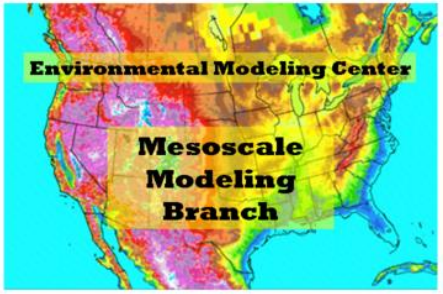
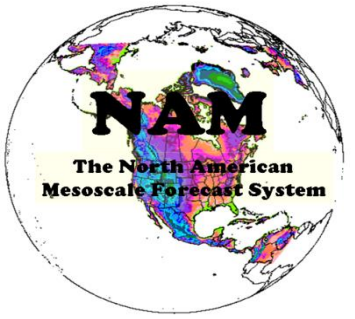
NCEP Director Decision Briefing

NAM V3.1

8 August 2014

Presented by
Eric Rogers





Presentation Outline

- Upgrade elements : what is changing and why
- Timeline
- Quantitative verification results
  - Real-time parallel
  - Retrospective testing
- A few case studies
- Known issues : what they are, what we think is causing them, and our future plans for mitigation
- Summary/Conclusion

Model Changes

- Replace legacy GFDL radiation with RRTM
- Modified Gravity Wave Drag/Mountain Blocking
  - More responsive to subgrid-scale terrain variability
  - Target : Improve synoptic performance without adversely impacting 10-m wind forecasts
- New version of Betts-Miller-Janjic convection
  - Moister convective profiles, convection triggers less
  - Target : Improve QPF bias from 12-km parent, esp. in warm season
- Ferrier-Aligo microphysics
- Modified treatment of snow cover/depth
  - Use forecast rime factor in land-surface physics
  - Target : Reduce snow depth in marginal winter conditions w/complex precipitation type
- Reduce roughness length for 5 vegetation types
  - Target : Improved 10-m wind in eastern CONUS

Model changes targeting NAM nests

- **Current NAM nests configuration**
  - 4 km CONUS, 6 km Alaska, 3 km Hawaii/Puerto Rico, 1.33 km (if in CONUS) or 1.5 km (if in Alaska) fire weather nest. CONUS/AK/HI/PR nests used as input to NAM Downscaled (NDFD) grids
  - Have "reduced" BMJ convective triggering
  - All run to 60-h except 36-h for fire weather nest
- **Nests in NAM upgrade; no change in resolution**
  - All nests except Alaska will run with explicit convection
  - Measures to improve convective signatures/structure:
    - Extensive modifications to microphysics (Ferrier-Aligo)
    - Reduce 2nd order diffusion in nests (improves horizontal storm structure in cases suggested by SPC)
    - Separate microphysics species advection for all nests except 6 km Alaska

Ferrier-Aligo Microphysics

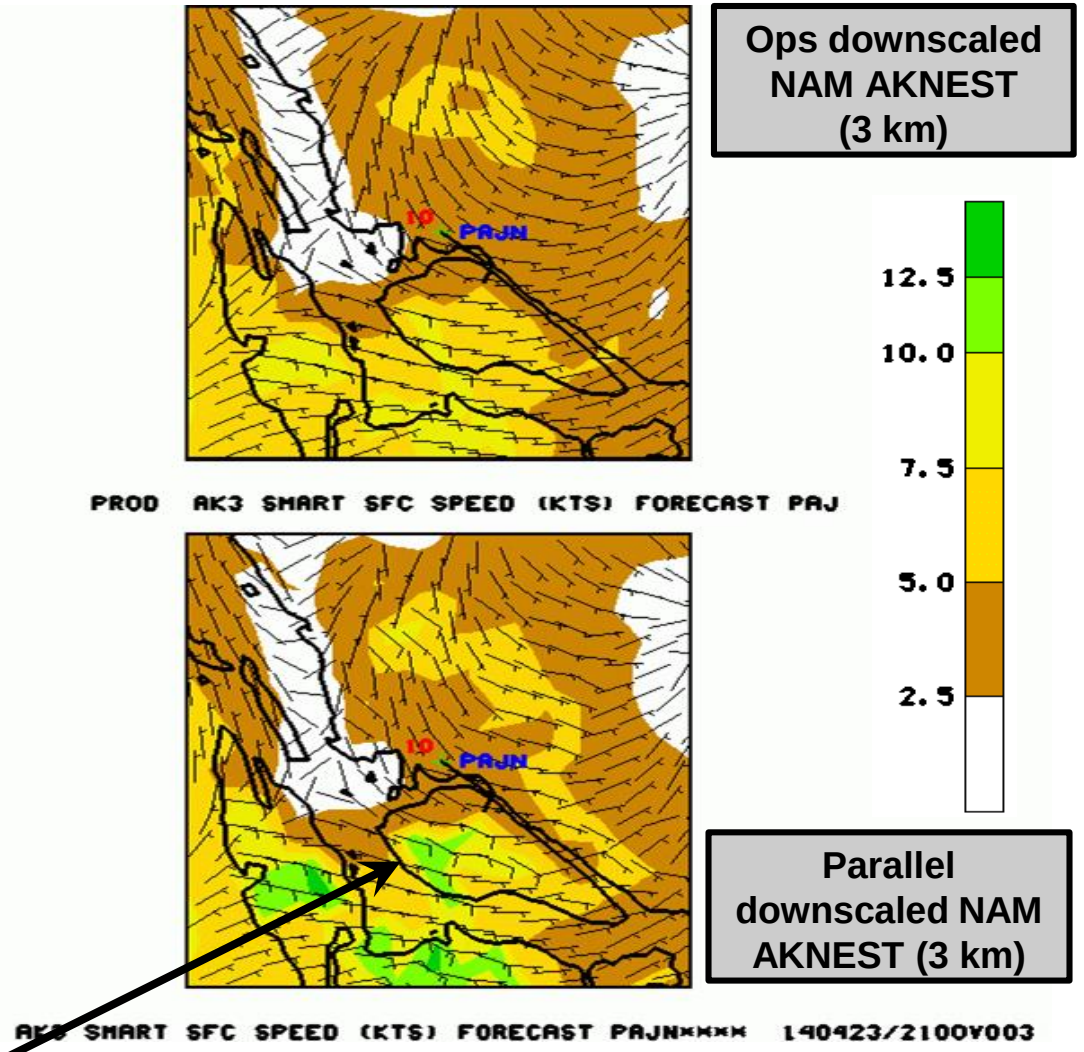
- **Advection of mass-weighted rime-factor (RF; i.e. "variable ice density").**
- **Max NLI (number concentration of large ice) a function of RF and temperature (no longer a constant).**
  - **"Stratiform mode" when RF<10, max NLI ranges from 10-20 L-1.**
  - **"Convective mode" when RF>=10, max NLI=1 L-1**
  - **"Hail mode" when RF>=10, mean diameters >=1mm (NLI=1 L-1).**
- **Promote more supercooled liquid water.**
- **Modest reduction in rimed ice fall speeds.**
- **Increased radar backscatter from wet, melting ice, and at T<0C when rain & ice coexist in intense updrafts.**
- **Combined radar return from rain and heavily rimed ice in areas of intense convection where either (a) ice is formed from freezing of rain drops or (b) rain is formed from melting of large ice.**
- **(Other changes related to cloud ice production not discussed here)**

Analysis/NDAS Changes

- Hybrid variational ensemble analysis
- New satellite bias correction scheme
- Variational Quality Control
- Raob level enhancement
- Use mesonet wind reject list from RTMA; use modified RTMA reject lists for all variables with most NWS Western Region Stations removed
- Use GFS ozone analysis in radiance assimilation
- Cloud analysis and diabatic digital filter initialization (12 km NDAS only)
- Resume calculation of NDAS long-term precip budget adjustment (used to bias correct Stage II/IV analyses) using CCPA
- New observation types
  - GPS bending angle data replaces refractivity
  - GOES-15 radiances
  - New VAD winds (higher vertical resolution, produced at NCEP w/radial wind QC)
  - Meteosat-10 wind subtypes w/different data thinning

Changes to Downscaled Grids

- 5 km CONUS / 6 km Alaska DNG grids extended to 192-h via DGEX
- Addition of Haines Index for Fire weather
- Improved 10-m wind treatment
  - Use mass-consistent wind field model
  - Based on velocity potential, incorporating local terrain gradients
- DGEX extension will not be on AWIPS simultaneously with NAM implementation, this will probably occur sometime during fall 2014.

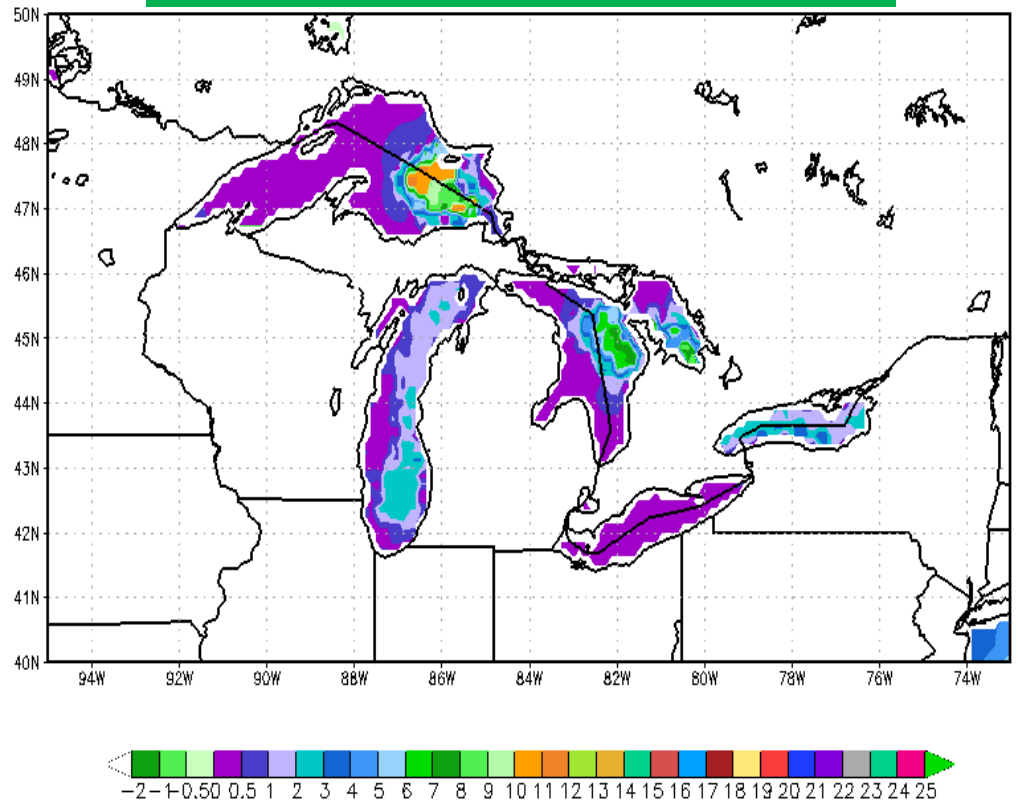


Other Changes

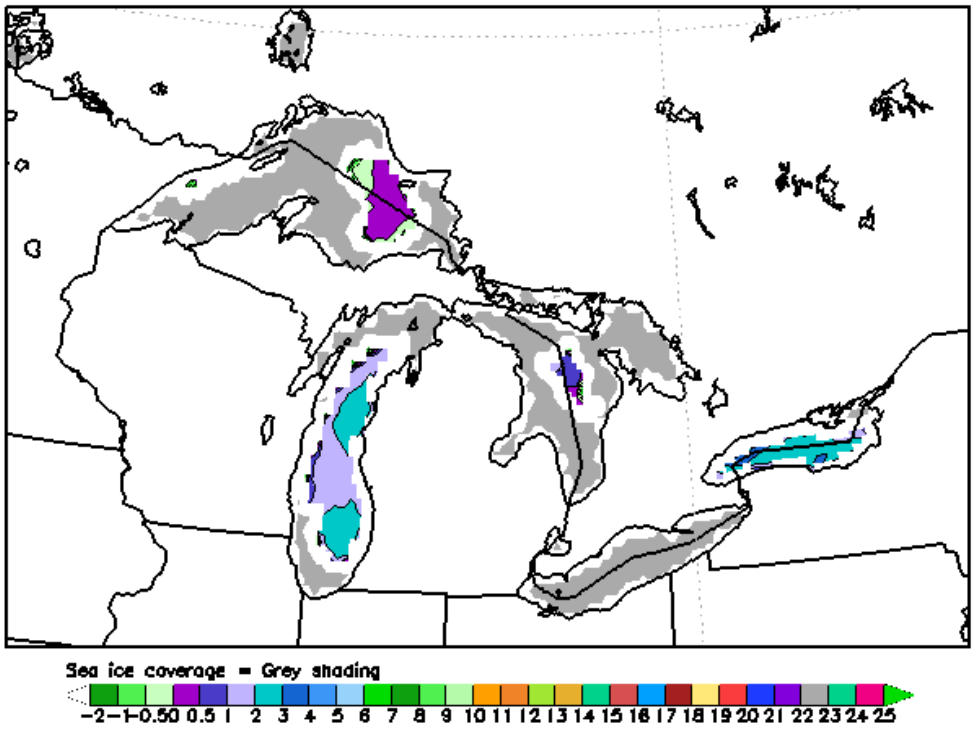
- **Discontinue use of the AFWA snow depth product in the NDAS due to quality control issues last winter.**
  - **NDAS snow depth will continuously cycle (similar to RAP).**
  - **Once per day (at start of 06z NDAS), snow will be removed at any point that is snow-free in the IMS snow cover analysis.**
  - **This is a temporary move as we anticipate use of NOHRSC and IMS snow depth products in the future.**
- **Discontinue use of GLERL water temperatures for the Great Lakes, use MMAB 1/12th deg RTG_SST_HR (SST used in the rest of the NAM domain).**
  - **GLERL product was too cool last fall and too warm this winter (see next slide; up to 10^{o}C too warm in ice-free parts of Lake Superior in Dec- late Jan).**
- **28 additional BUFR sounding stations**

Example of Great Lakes SST problem 30 January 2014

OPS NAM w/GLERL Lake Temp
Ice coverage not shown



PLL NAM w/RTG_SST_HR Lake Temp
Ice coverage = Grey shading

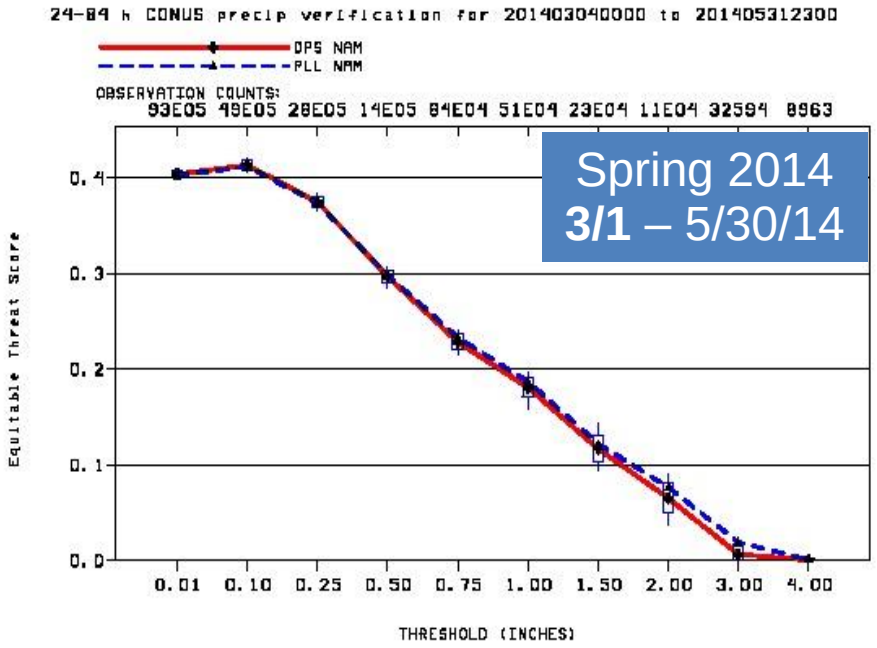


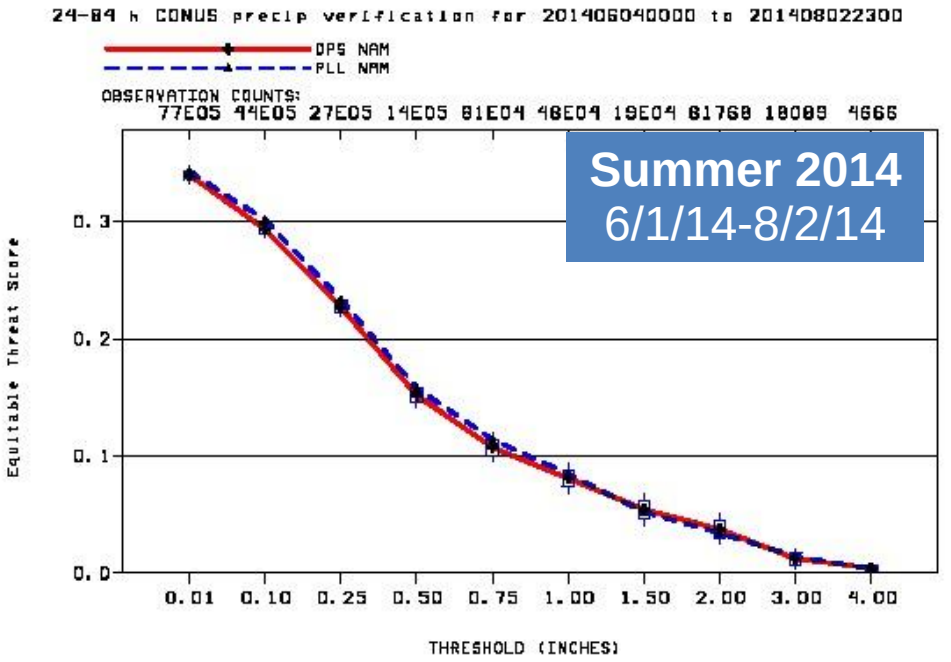
Timeline

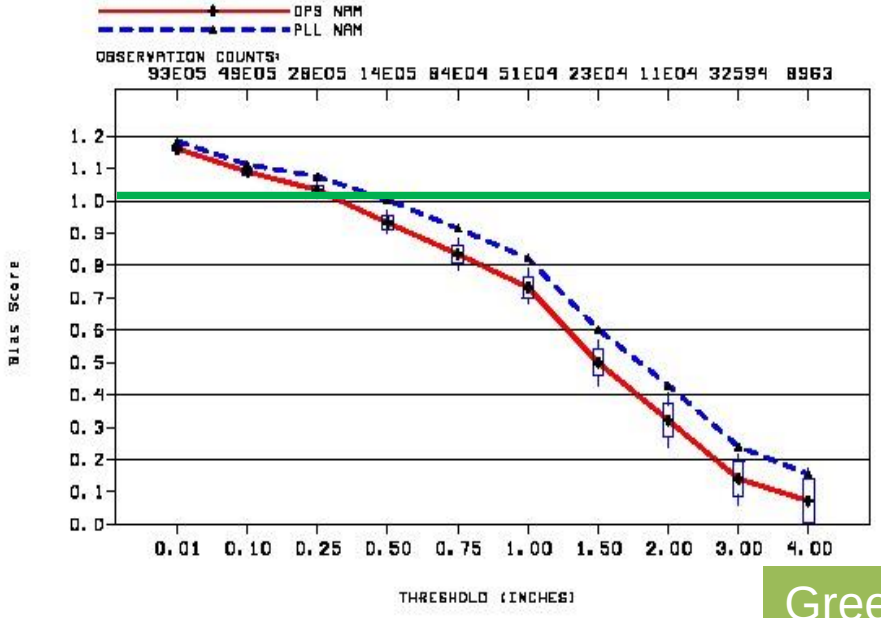
- **Real-time testing has been ongoing since late 2011; dates when major components were introduced:**
  - RRTM : First version Feb 2012, development ongoing until code was frozen
  - Hybrid GSI w/global EnKF : April 2012, final GSI version Mar 2014
  - Modified BMJ : July 2012, upgraded Jan 2013
  - GWD/MB : Tuning started in 2012, major overhaul of code June/July 2013, finalized March 2014
  - Ferrier/Aligo microphysics : Tuning during 2013, in parallel as of Nov 2013, finalized Jan 2014
  - All major components frozen in March, final bug fix prior to handoff on 1 May 2014
- **Retrospective testing**
  - July 2011 (for CMAQ)
  - 1 December 2012 – 28 February 2013 (cool season for MDL's NAM MOS tuning)
  - 1 June 2013 – 31 August 2013 (warm season for MDL NAM MOS tuning, run is ongoing and will continue beyond proposed implementation date)
  - Many case studies using NAM launcher by B.Ferrier/E. Aligo (GWD tuning; DC Derecho; May 2013 Moore, OK tornado)
  - NAM launcher tests (12-km and 4 km) for all seasons tuning many aspects of RRTM, including cloud-radiation interaction (Ferrier, H-M. Lin)

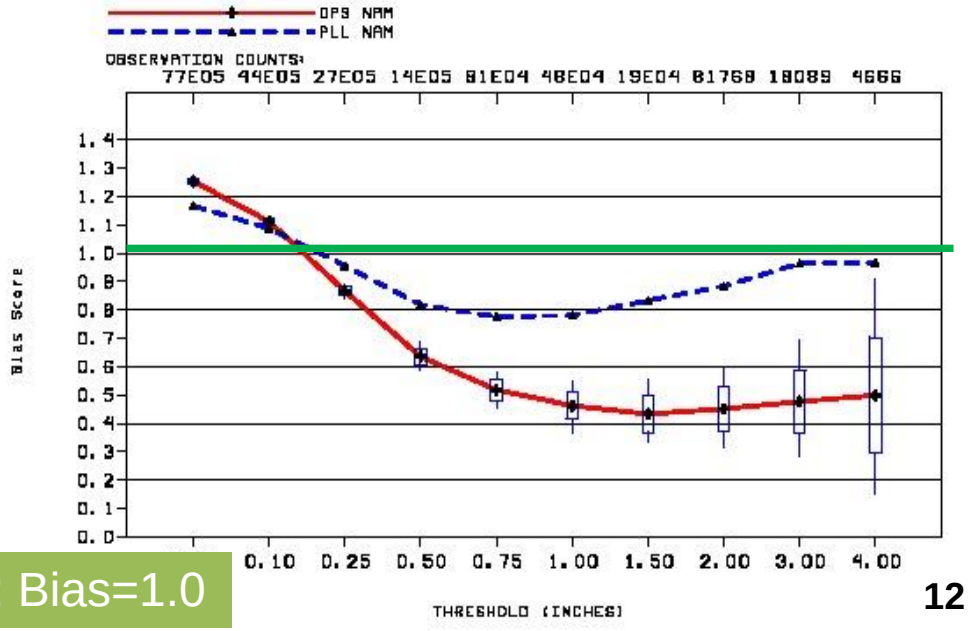
Quantitative skill scores: Spring and Summer 2014

Seasonal 24-h QPF ETS (top)/Bias (bottom) : Ops (red) vs Pll (blue) NAM 12 km over CONUS; all forecasts







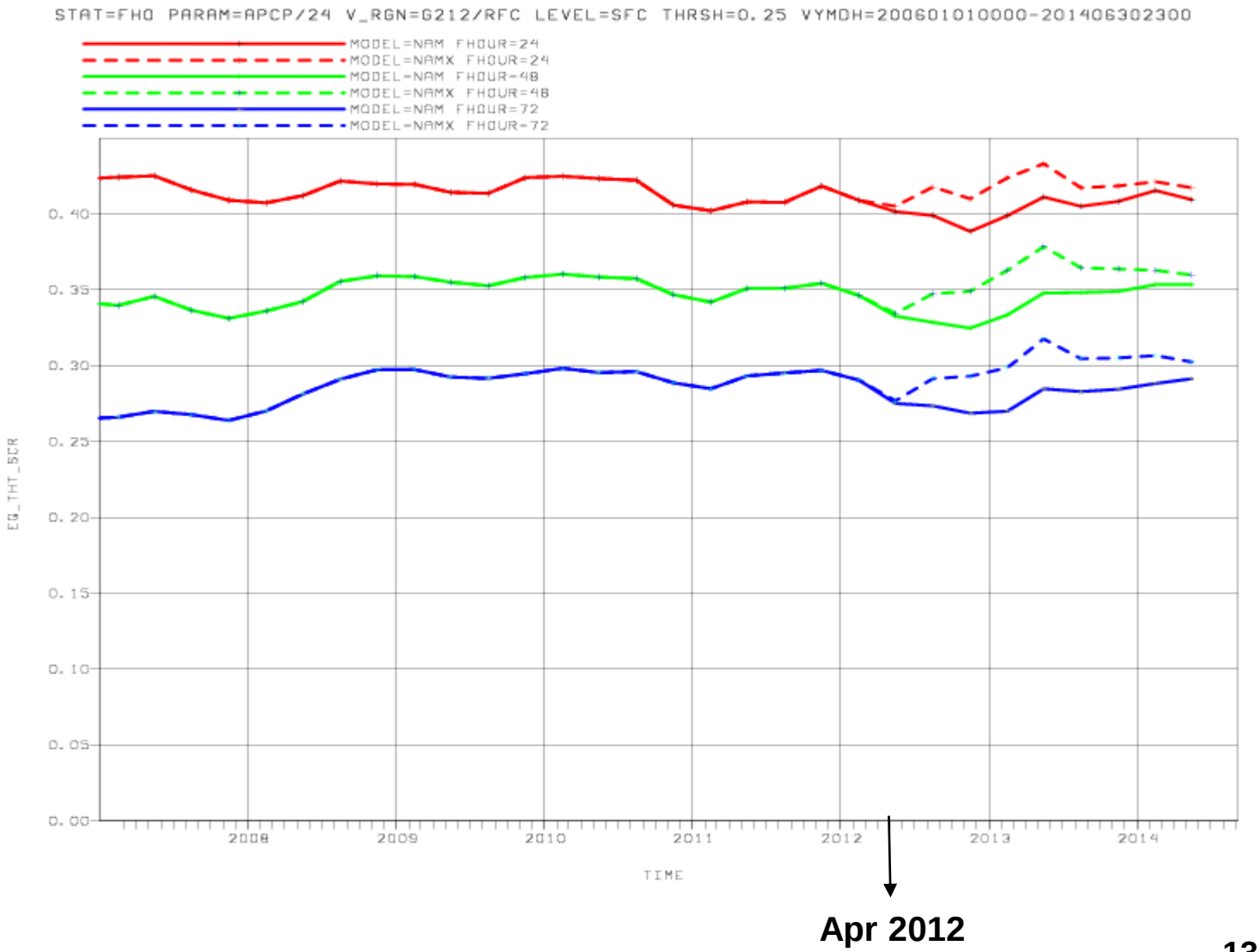


Green Line : Bias=1.0

Ops NAM, current Parallel NAM(dashed line) 24,48,72h forecasts, 2007-2014Q3

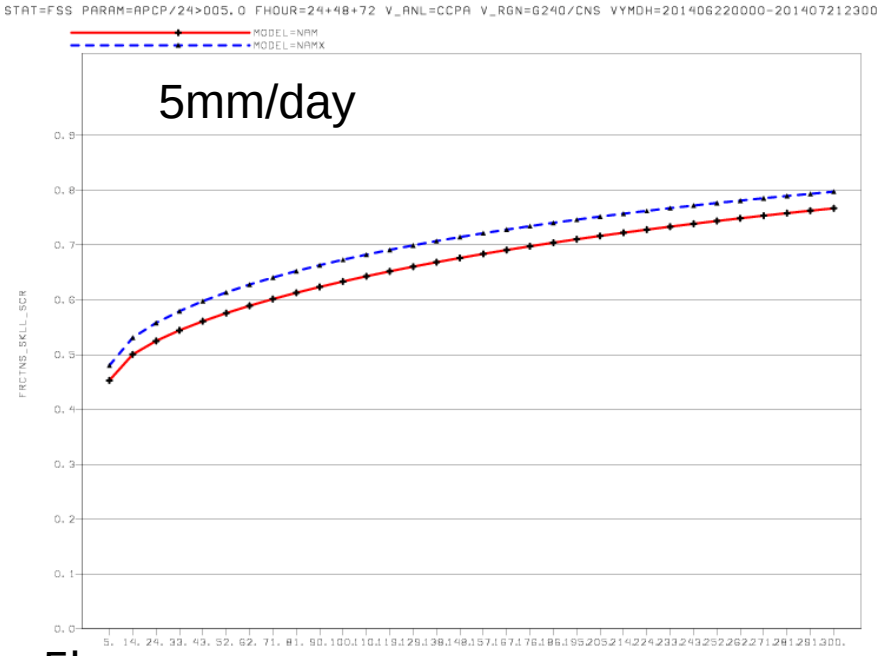
ETS at 0.25”/day

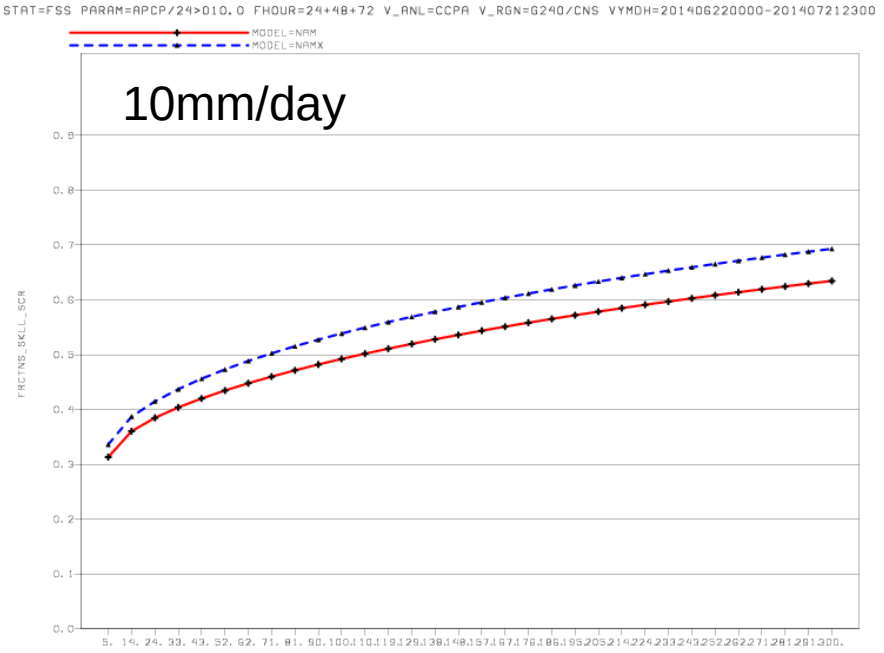
Quarterly time series, averaged over 4 quarters to remove seasonal variation



Apr 2012

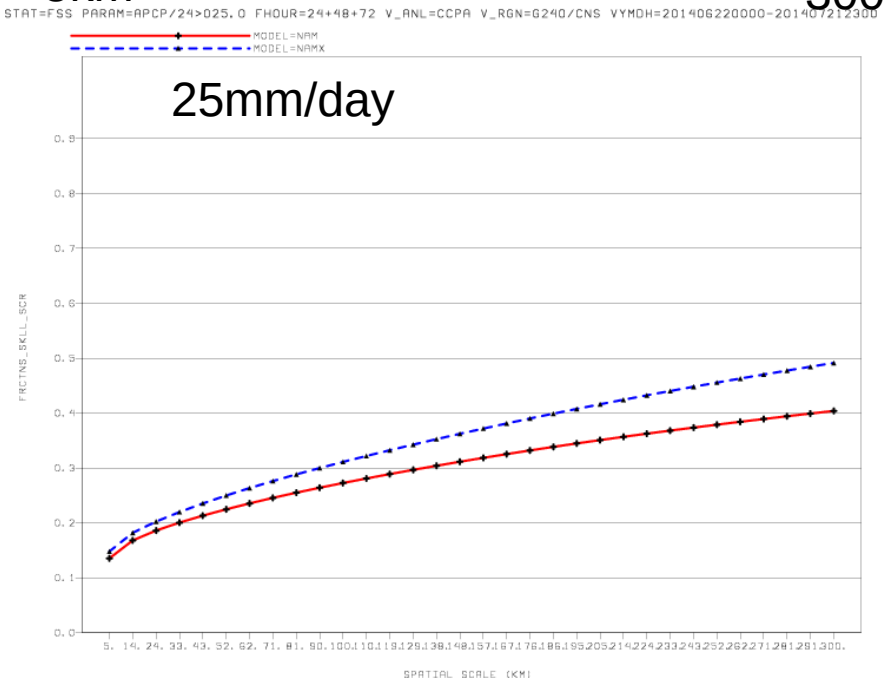
NAM, NAMX 24+48+72h Fractional Skill Score, 22 Jun – 21 Jul 2014

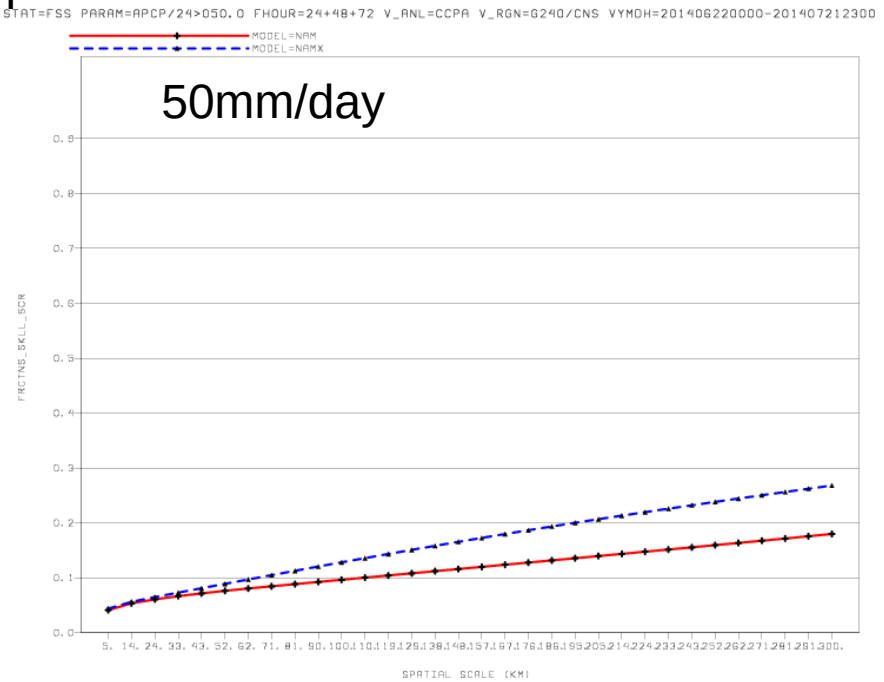




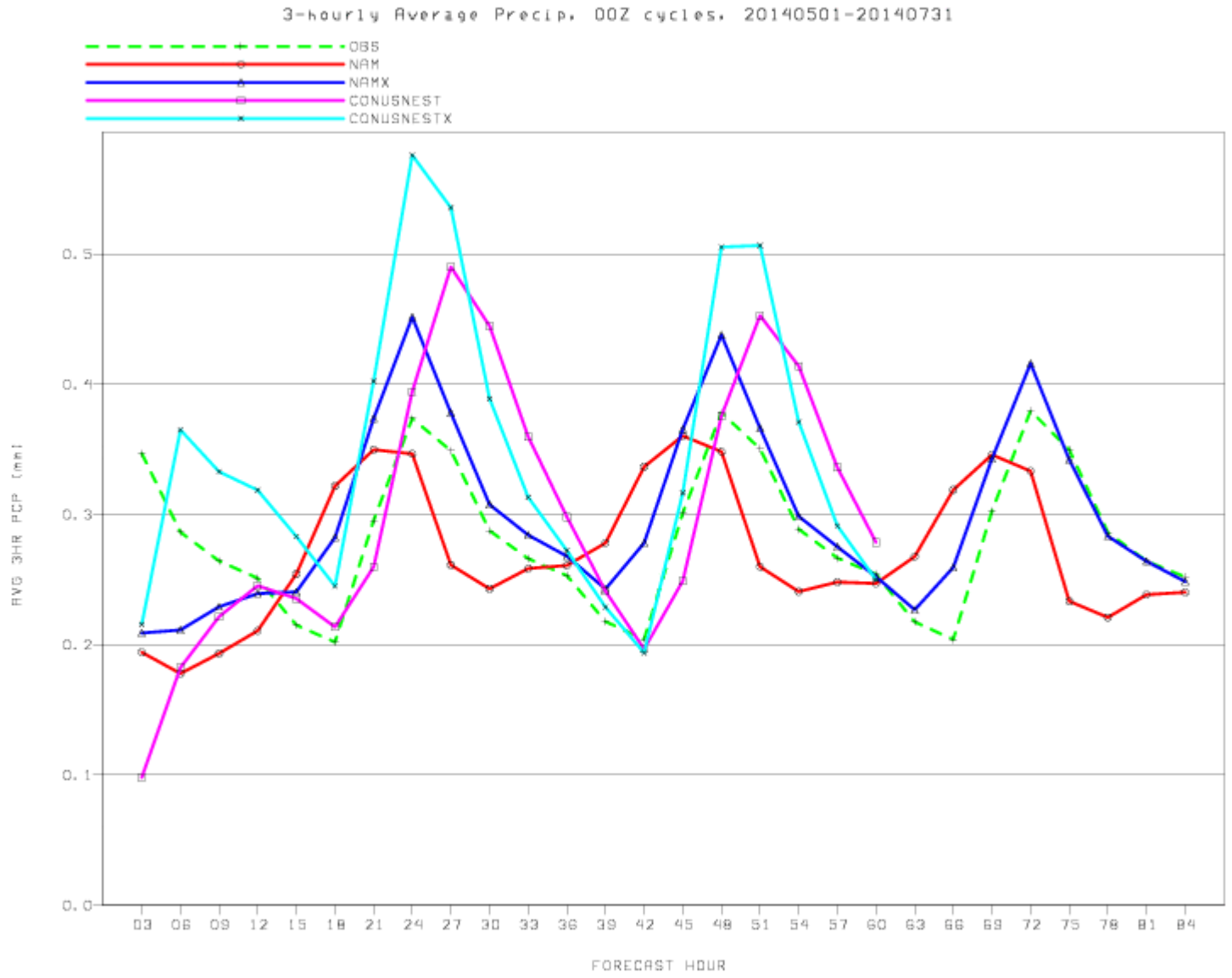
5km

300km

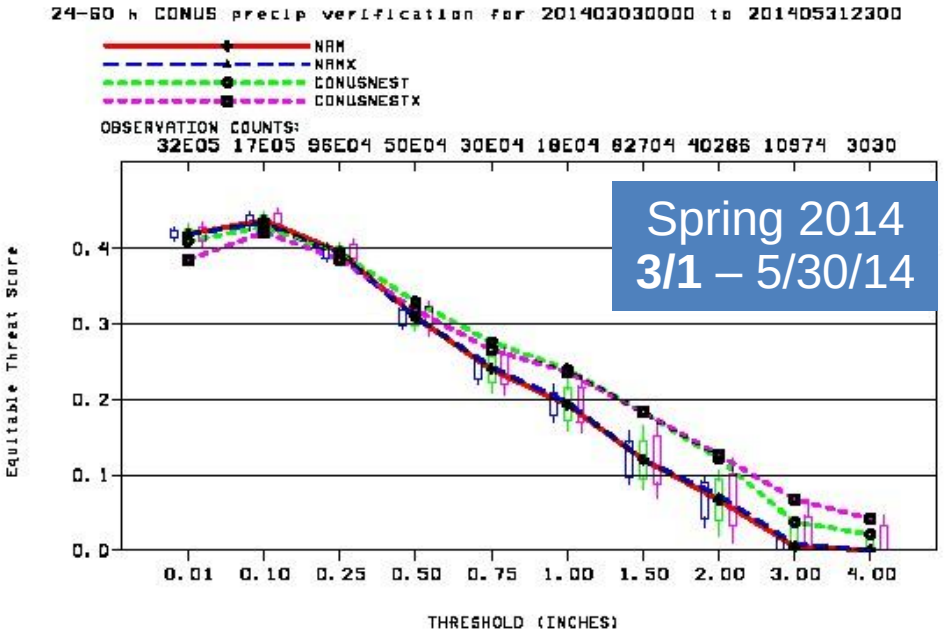


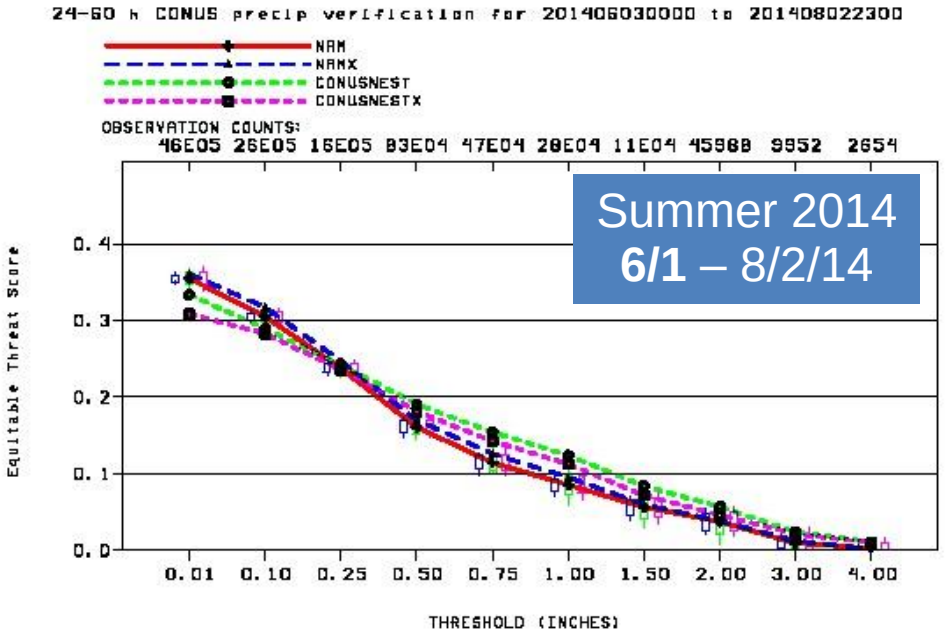


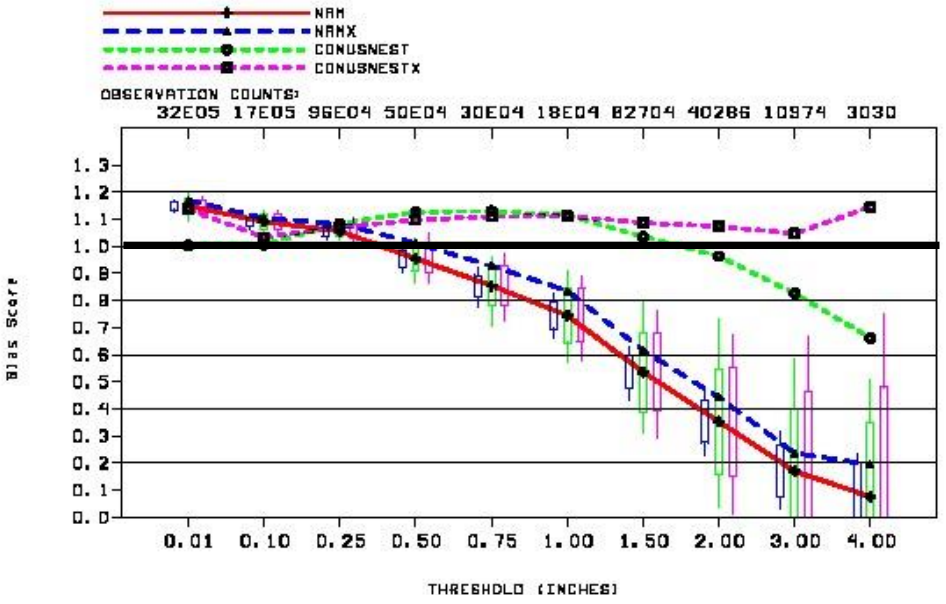
3-h Average Precip over CONUS for 5/1/14-7/31/14: Obs=green; Ops NAM12=Red; Pll NAM12=Blue; Ops NAM4=Magenta; Pll NAM4=Cyan

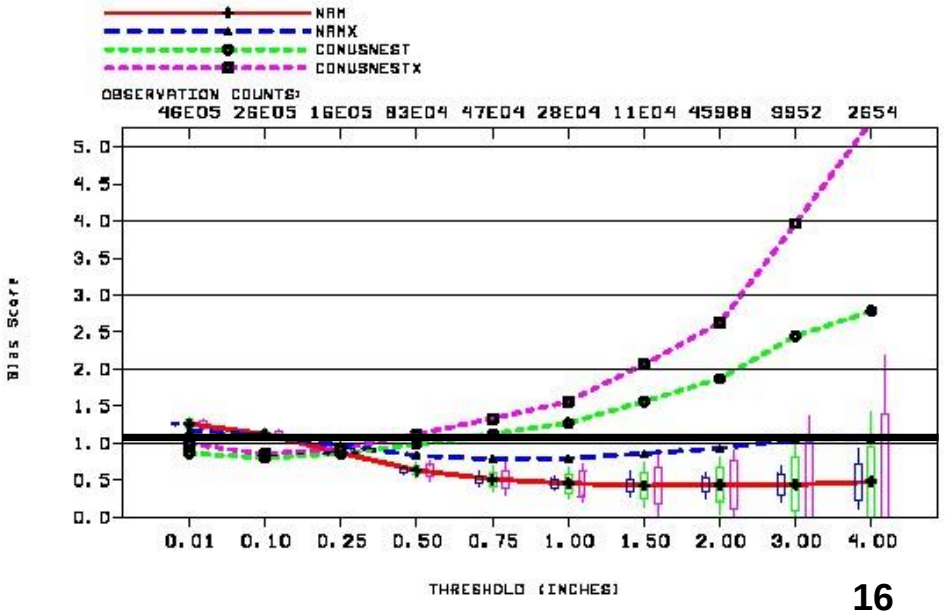


24-h QPF scores for NAM ops and pll parent and CONUS nests (Pll nest ran @00z only from 9/26/13 – 6/17/14, all 24-h fcsts)



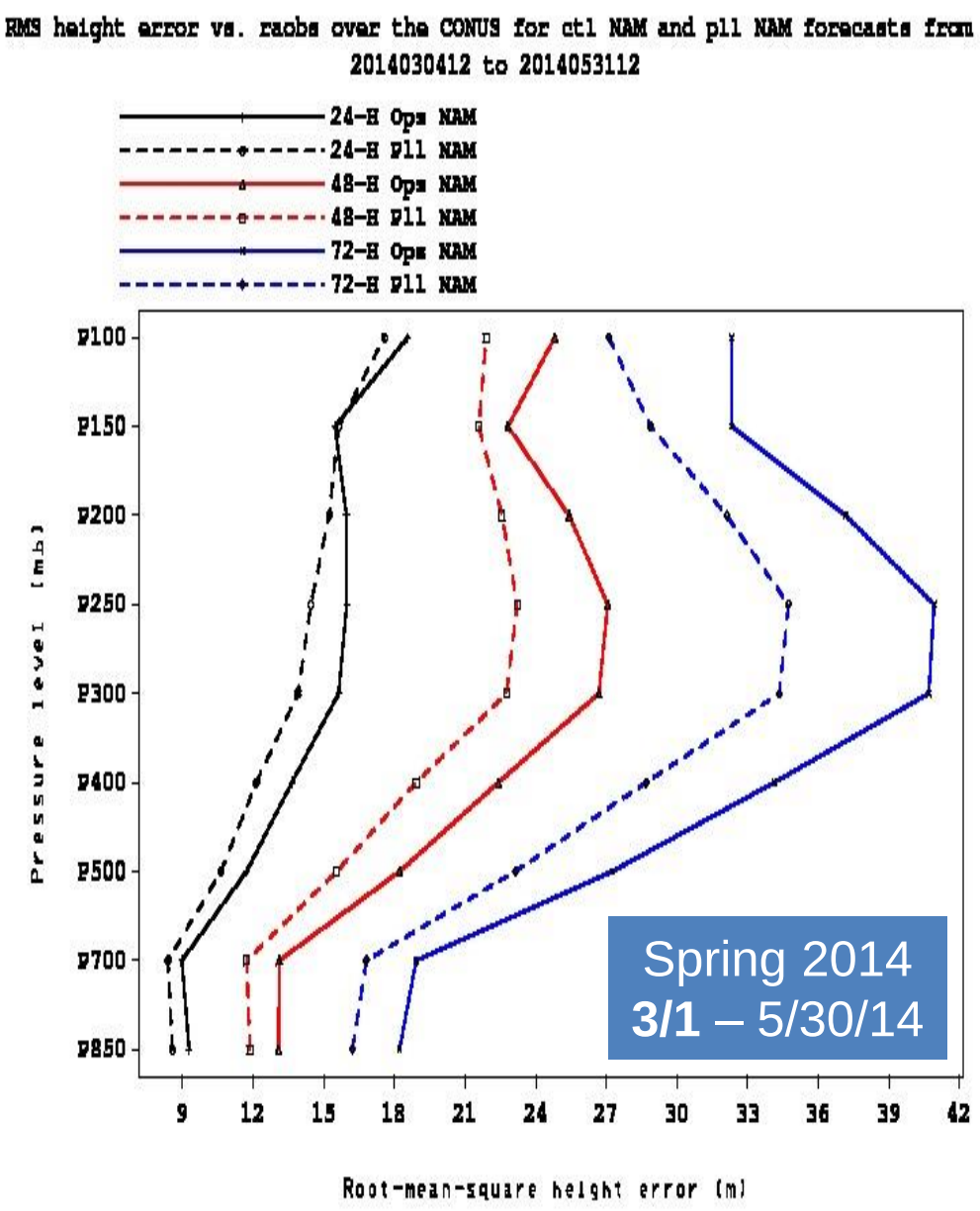


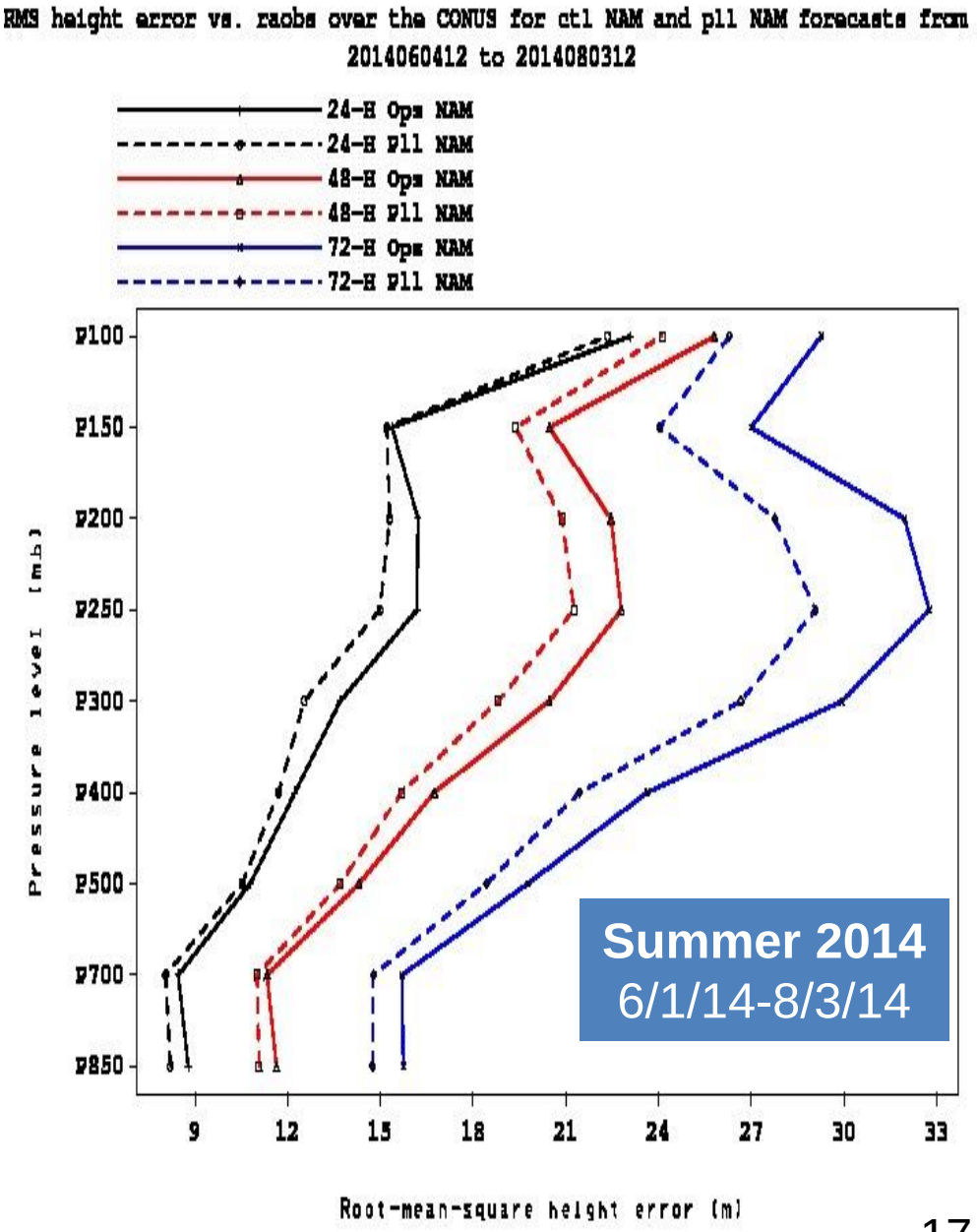




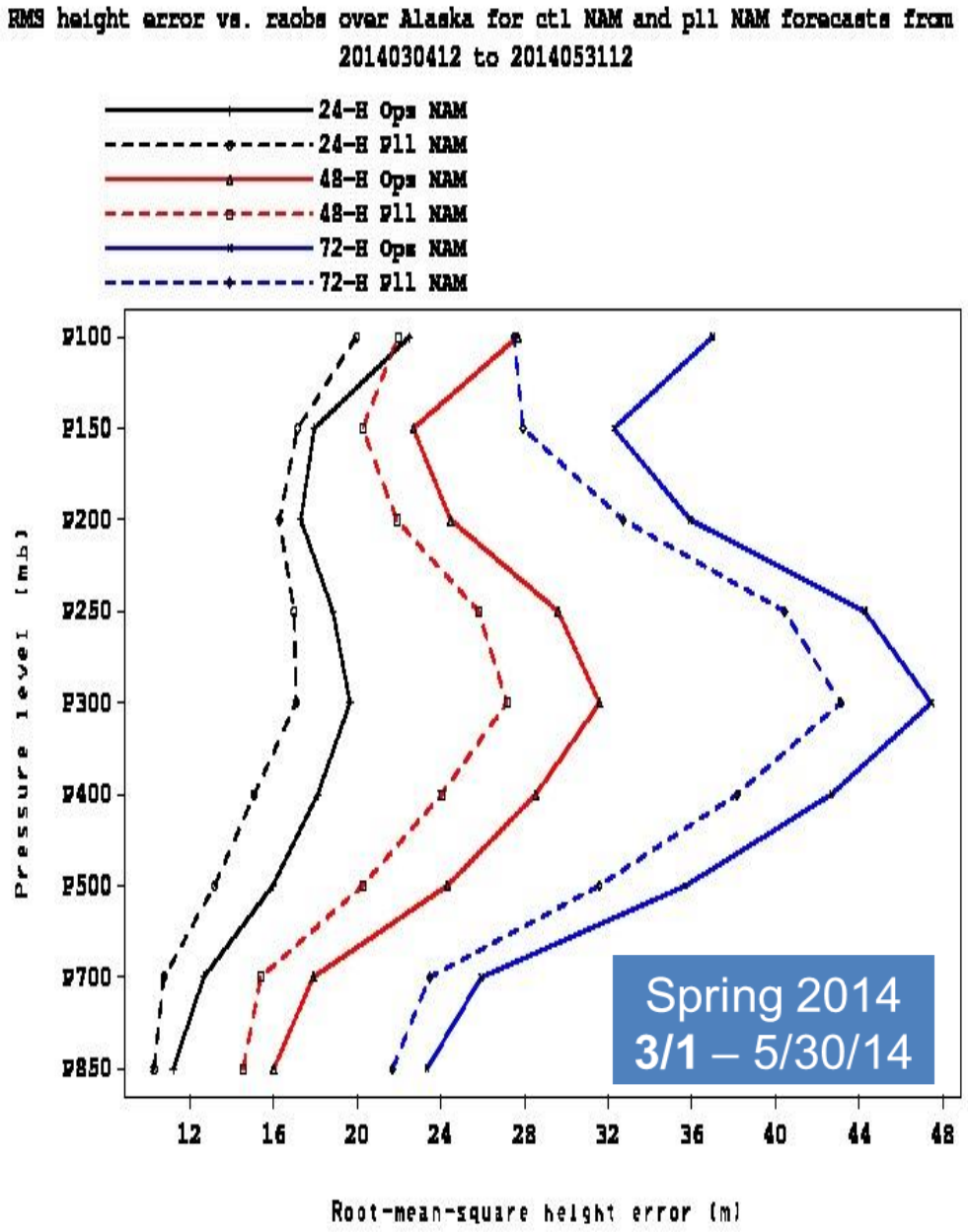
Ops NAM12=red; Pll NAM12=blue; Ops CONUS4=green; Pll CONUS4=magenta

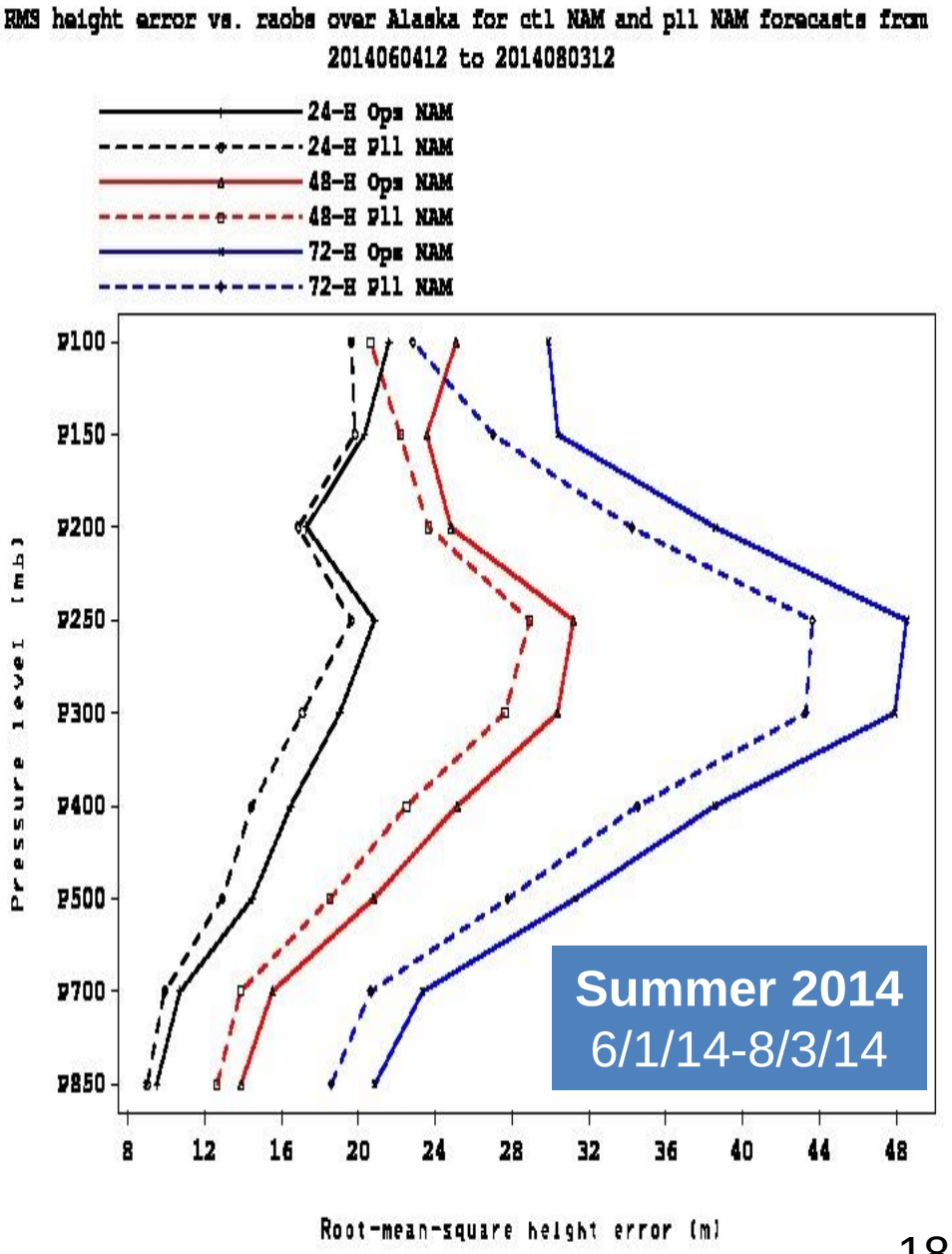
Ops NAM (solid) vs Pll NAM (dashed) : Day 1 (black), Day 2 (red), Day 3 (blue) RMS Height Error over CONUS



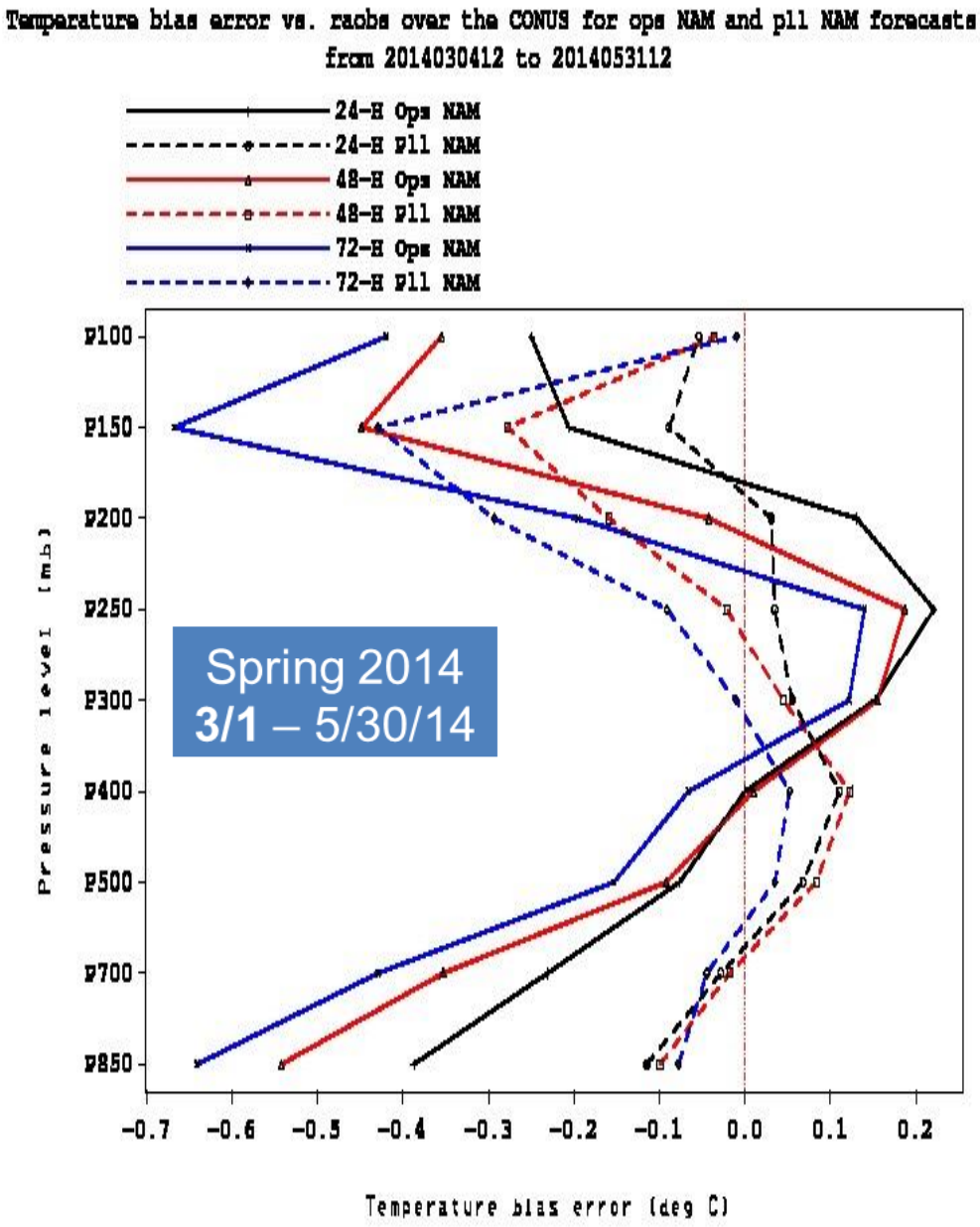


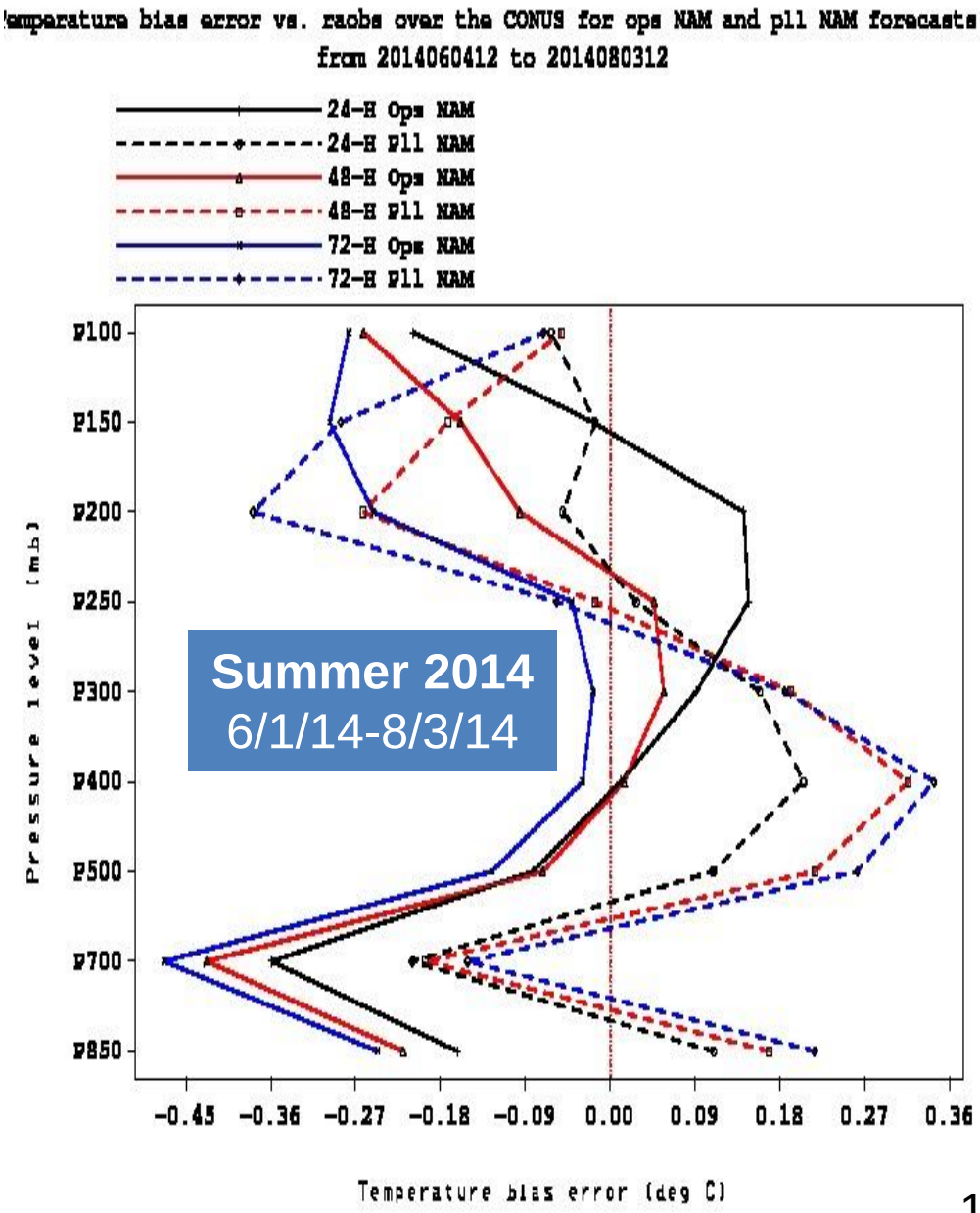
Ops NAM (solid) vs Pll NAM (dashed) : Day 1 (black), Day 2 (red), Day 3 (blue) RMS Height Error over Alaska



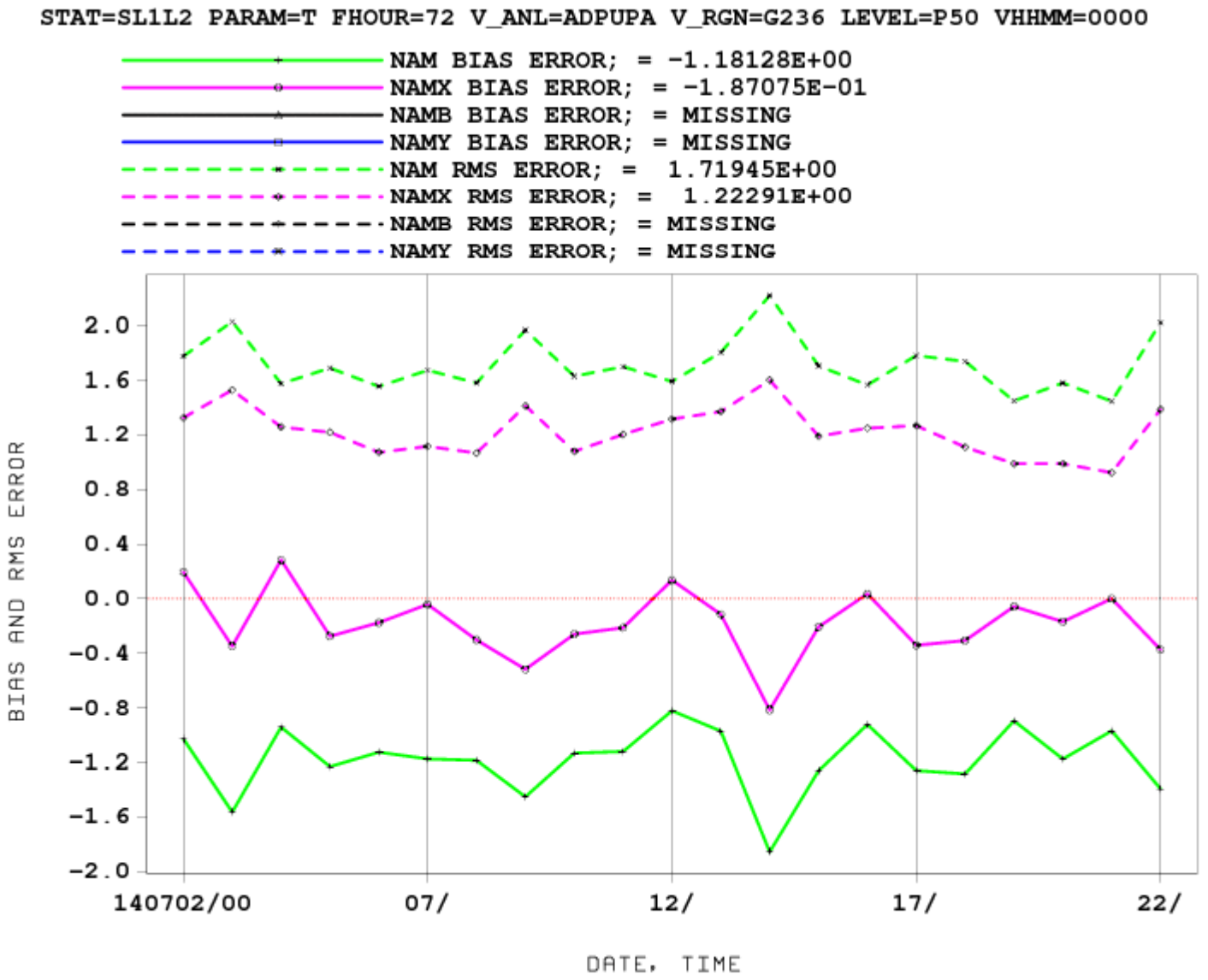


Ops NAM (solid) vs Pll NAM (dashed) : Day 1 (black), Day 2 (red), Day 3 (blue): Temperature Bias over CONUS



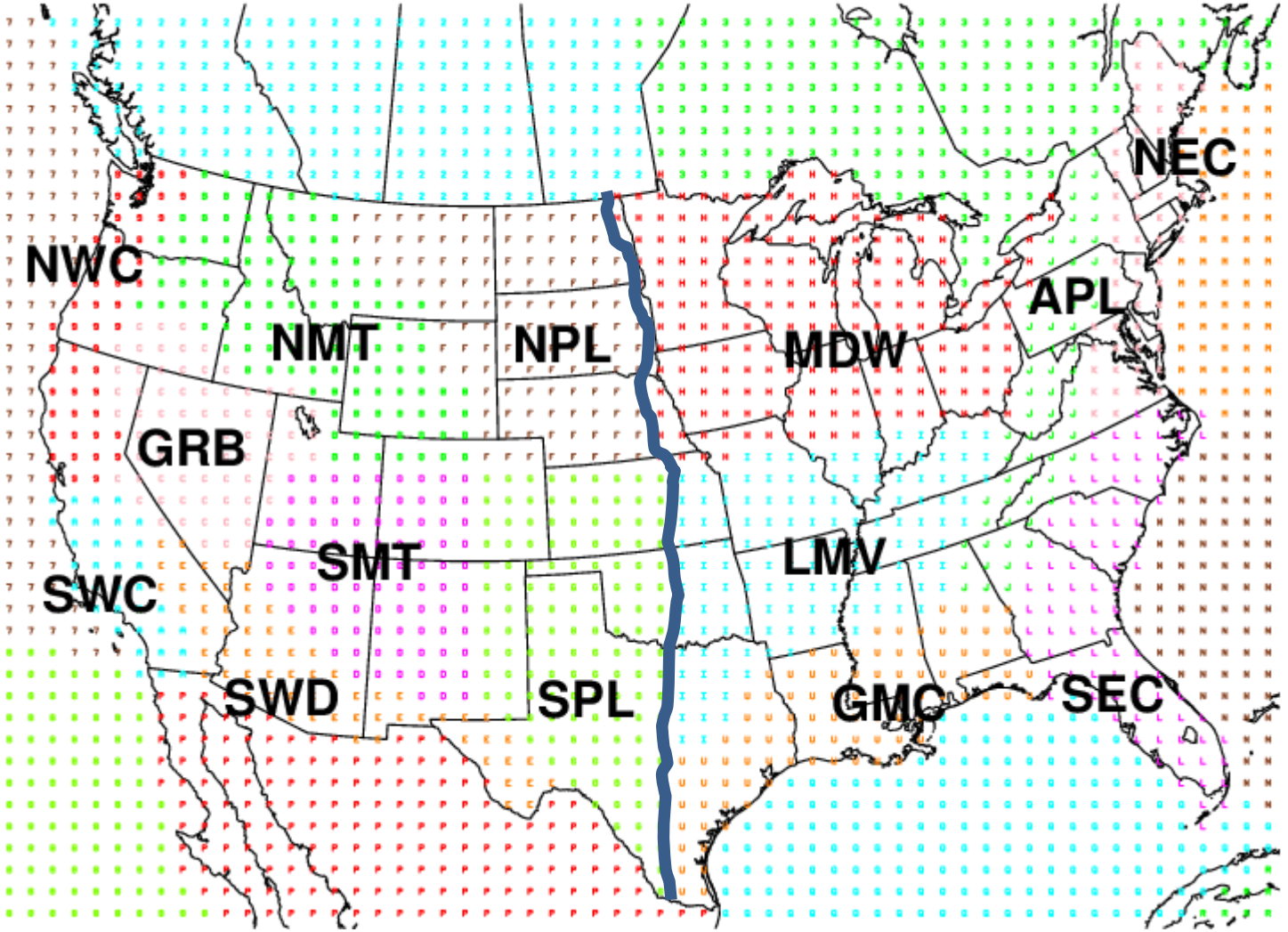


72-h fcst from 00z cycle: 50 mb Temp RMS/Bias error from 7/2-7/22/14 : Ops = Green, Pll = Magenta



Much lower bias in parallel; positive impact of RRTM

FVS Regions : Solid line is demarcation between East and West CONUS

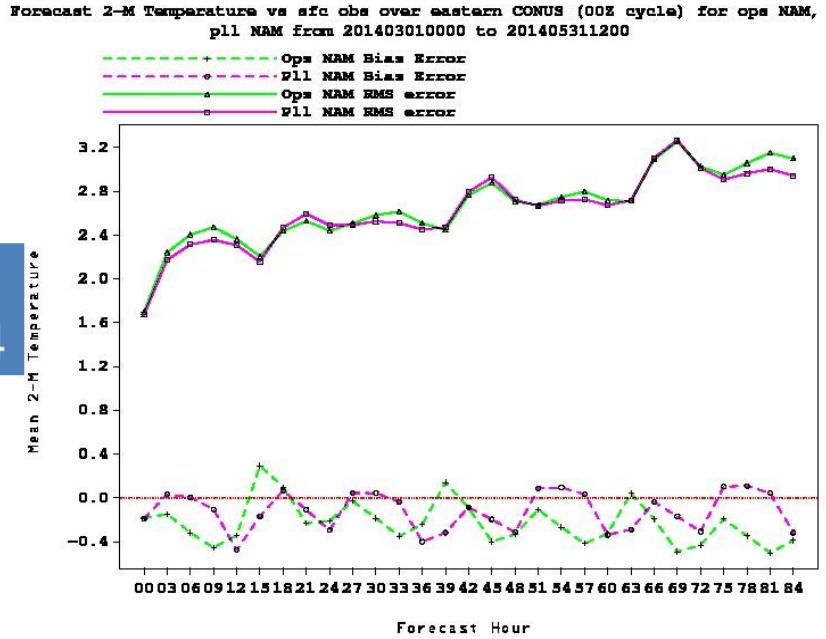


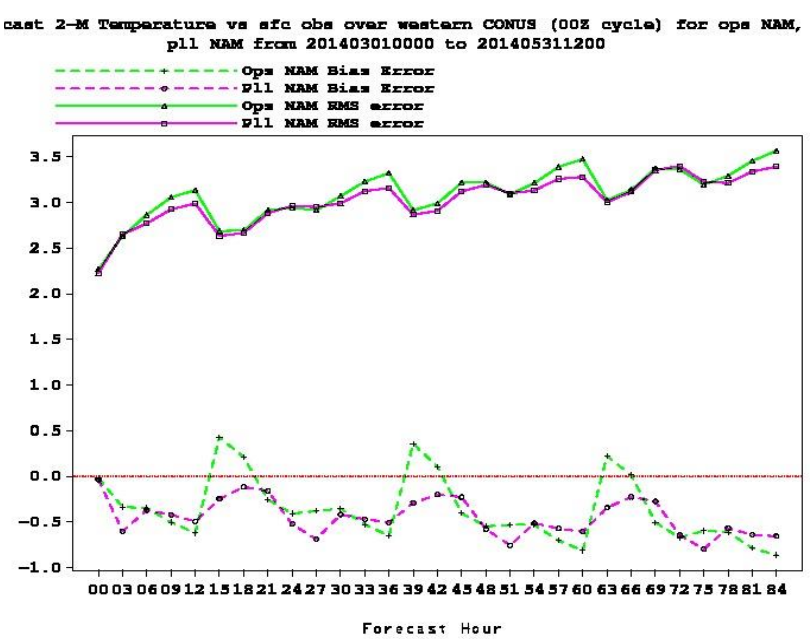
Surface fields : 2-m T RMS (solid) / bias (dashed) error over CONUS: 00z cycles; Green=ops, Magenta=pll

East CONUS

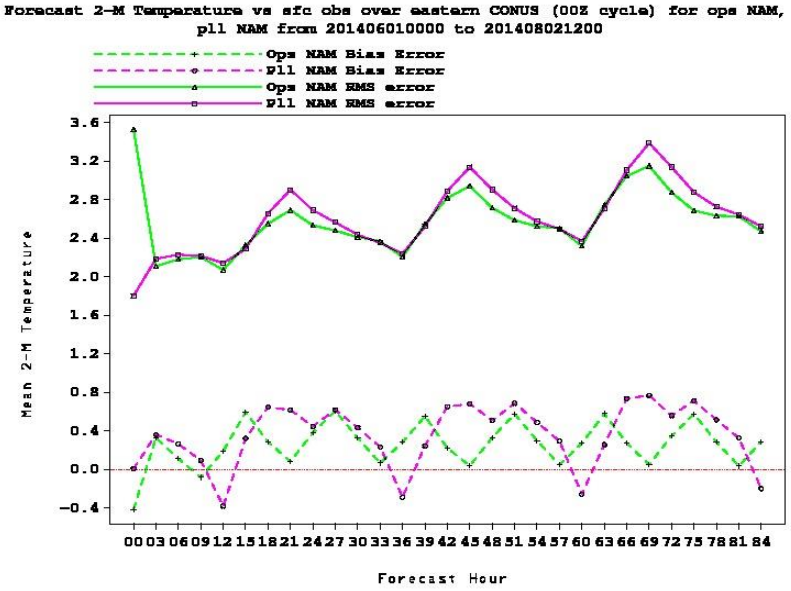
West CONUS

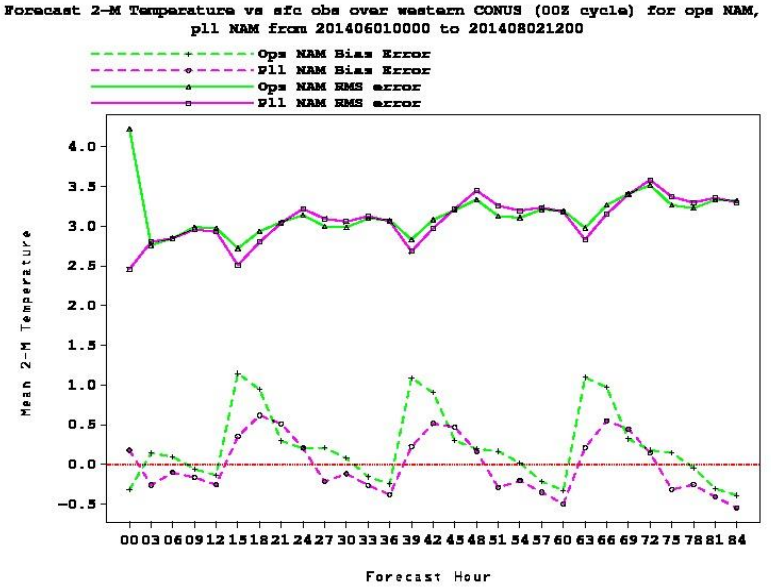
Spring 2014
3/1 – 5/30/14





Summer 2014
6/1/-8/3/14

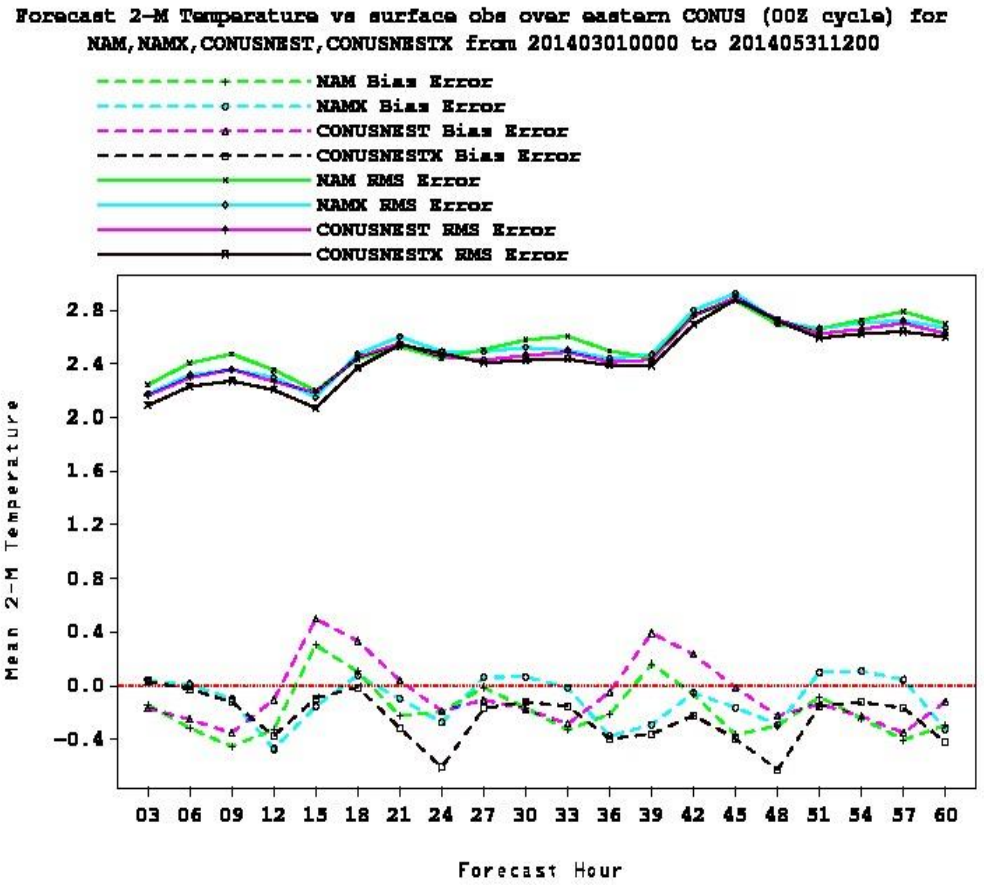




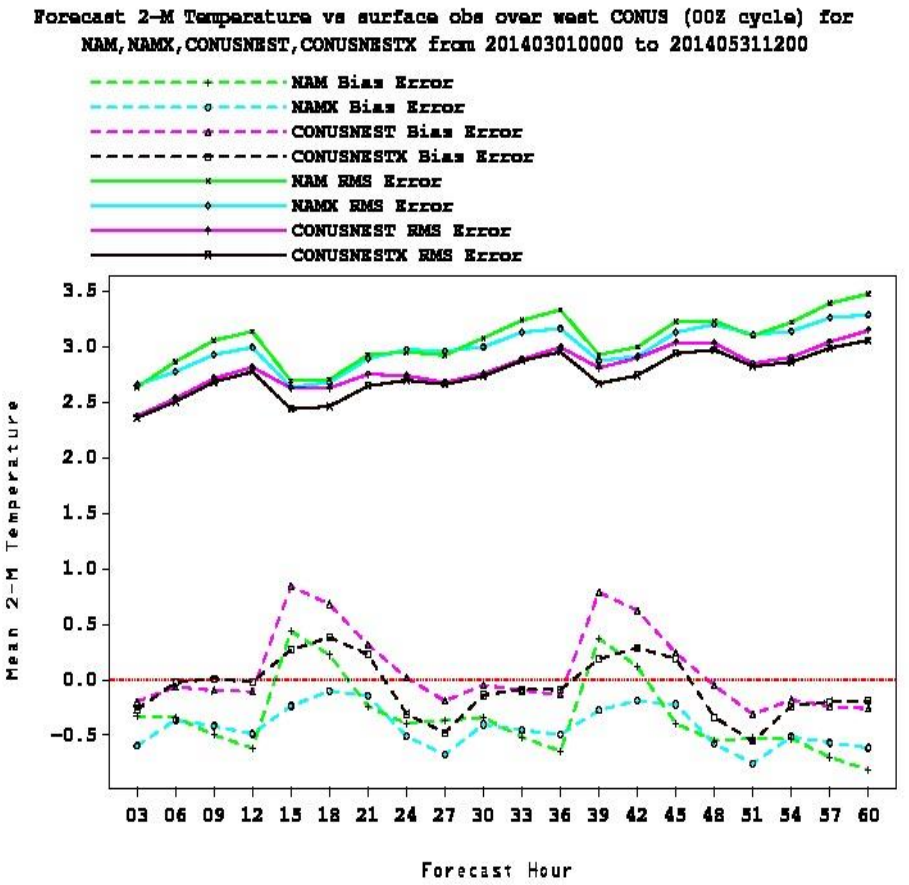
Surface fields : 2-m T RMS (solid) / bias (dashed) error over CONUS: 00z cycles; NAM12 vs NAM4 for 3/1-5/31/2014

Green=Ops NAM12; Cyan=Pll NAM12; Magenta=Ops NAM4; Black=Pll NAM4

East CONUS



West CONUS



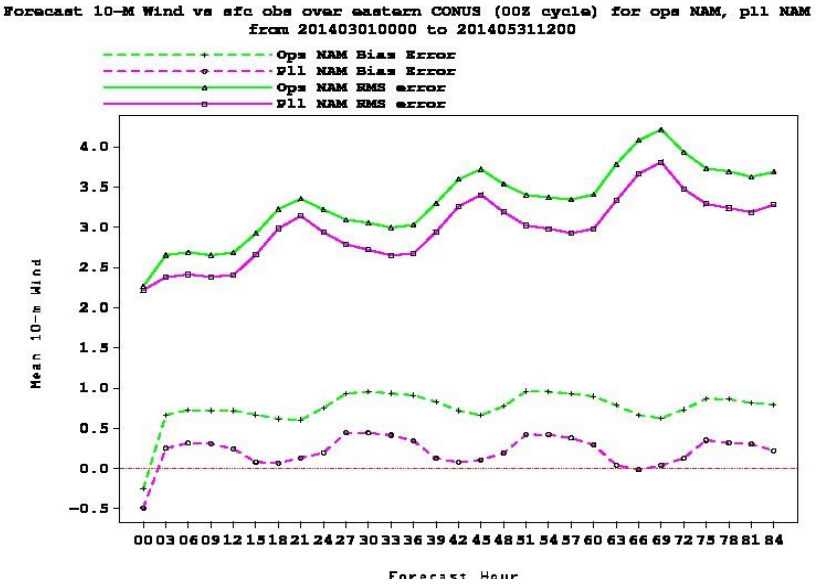
East CONUS : Pll NAM4 generally has lower (worse) bias than Pll NAM12
West CONUS : Pll NAM5 has higher (better) bias than Pll NAM12

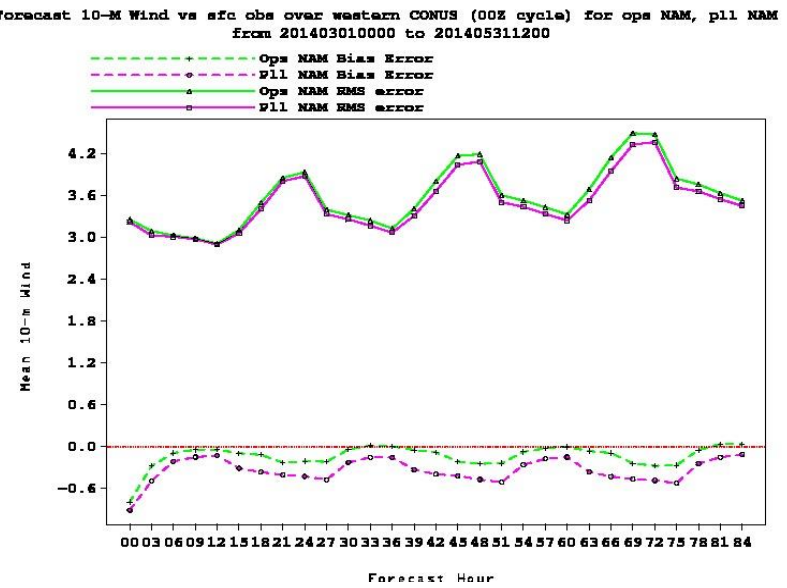
Surface fields : 10-m Wind RMS (solid) / bias (dashed) error over CONUS: 00z cycles; Green=ops, Magenta=pll

East CONUS

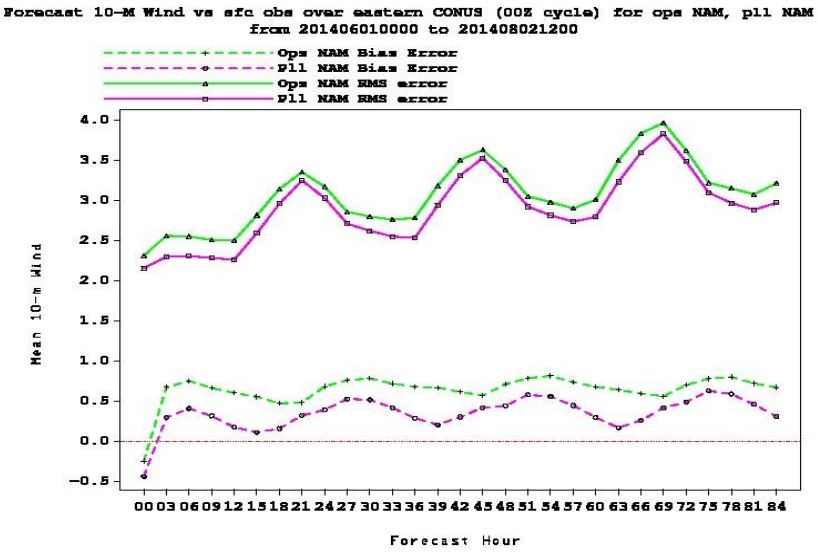
West CONUS

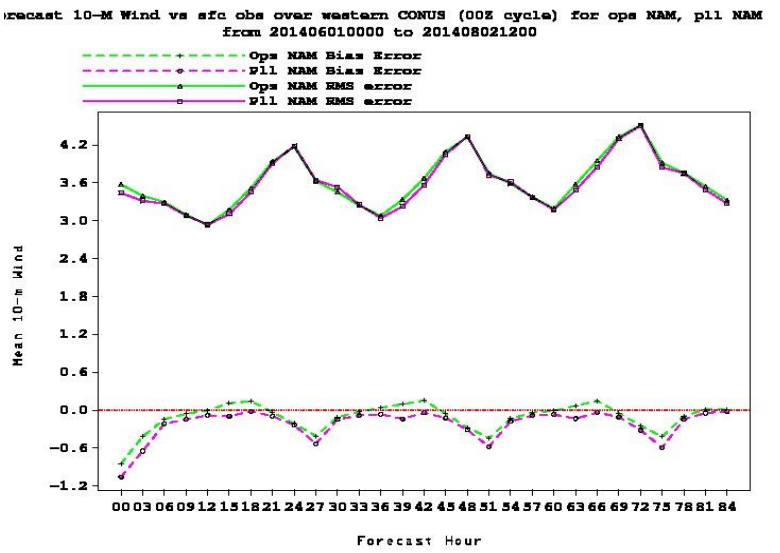
Spring 2014
3/1 – 5/30/14





Summer 2014
6/1/-8/3/14



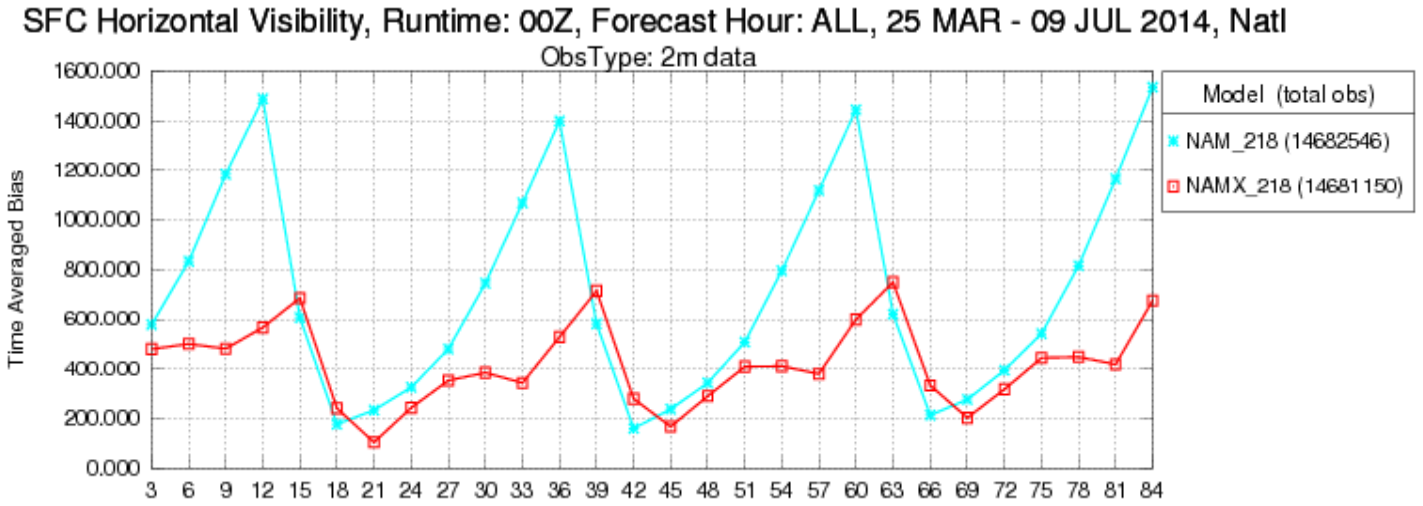


Reduced high 10-m wind bias in East CONUS with roughness length changes

Summary of visibility/cloud base height verification (courtesy of Brad Ferrier)

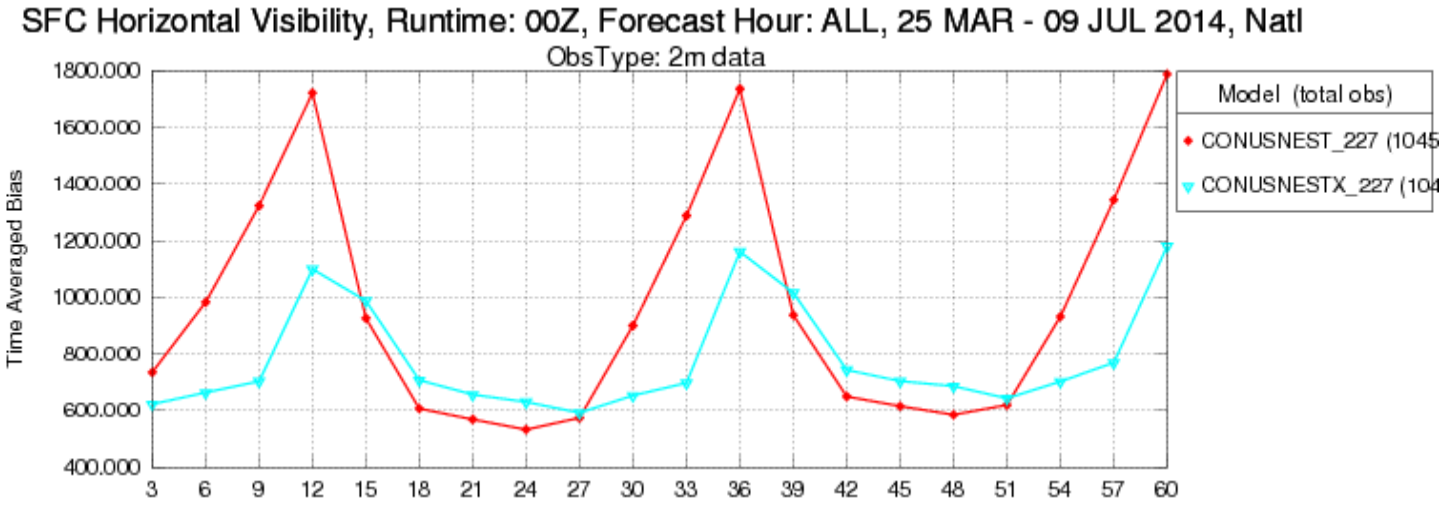
Average Visibility Verification Statistics (Bias) CONUS; 00Z Runs for 25 March - 9 July 2014

NAM-12 (parallel is red)



- **PLL NAM-12: <u>lower high bias</u> (improved) in visibility, esp at 12Z vs Ops NAM high bias.**

NAM-4 (parallel is blue)

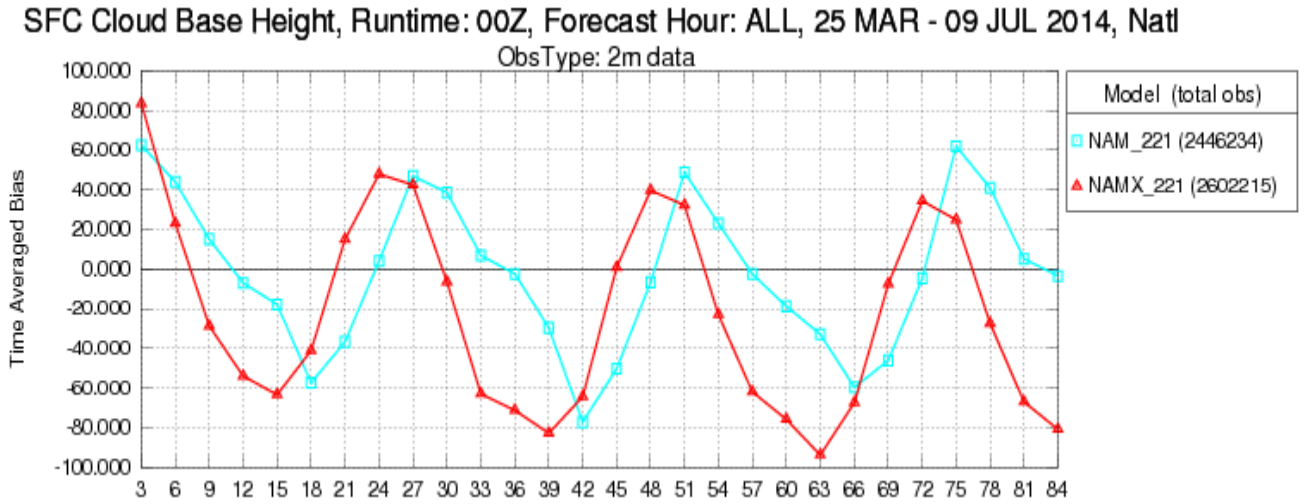


- **PLL C-Nest: <u>lower high bias</u> (improved) in visibility, esp at 12Z vs Ops C-Nest high bias.**

Note: RMS error differences were very small for both NAM-12 and NAM-4

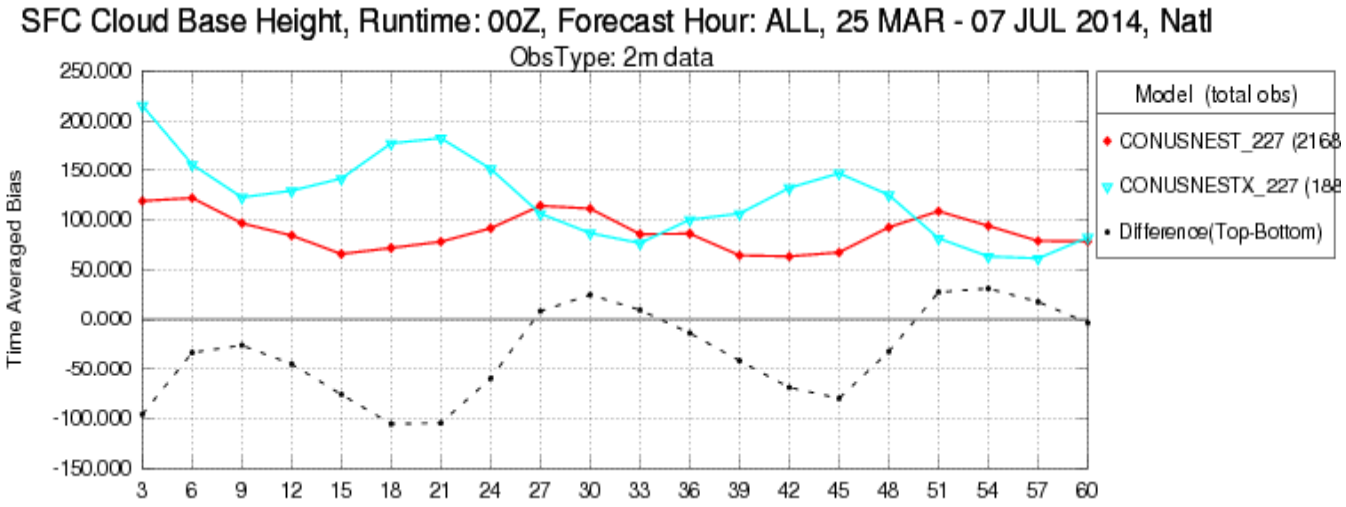
Average Cloud Base Hgt Verification Statistics (Bias) over CONUS 00Z Runs for 25 March - 9 July 2014

NAM-12 (parallel is red)



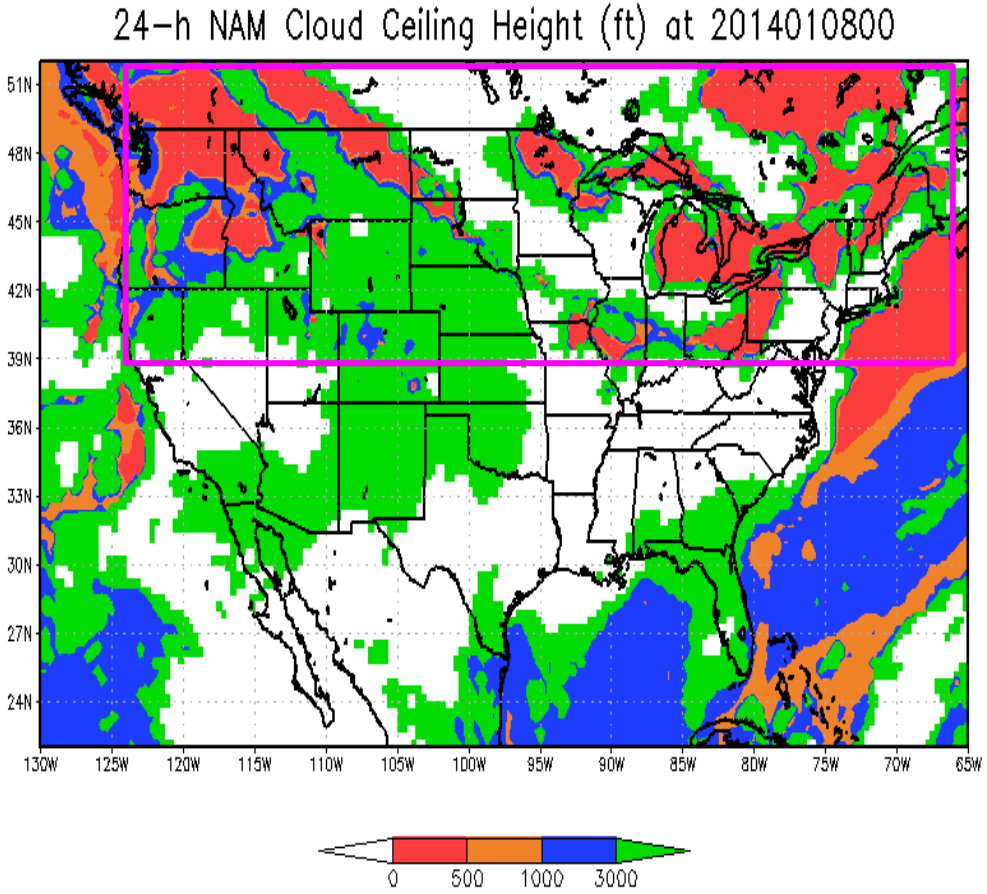
- **Pll NAM: <u>low bias</u> in cloud-base heights from 06Z to 15Z, 3-h shift w/r/t Ops NAM.**
- **Pll NAM: lower RMSEs for all hours (not shown)**

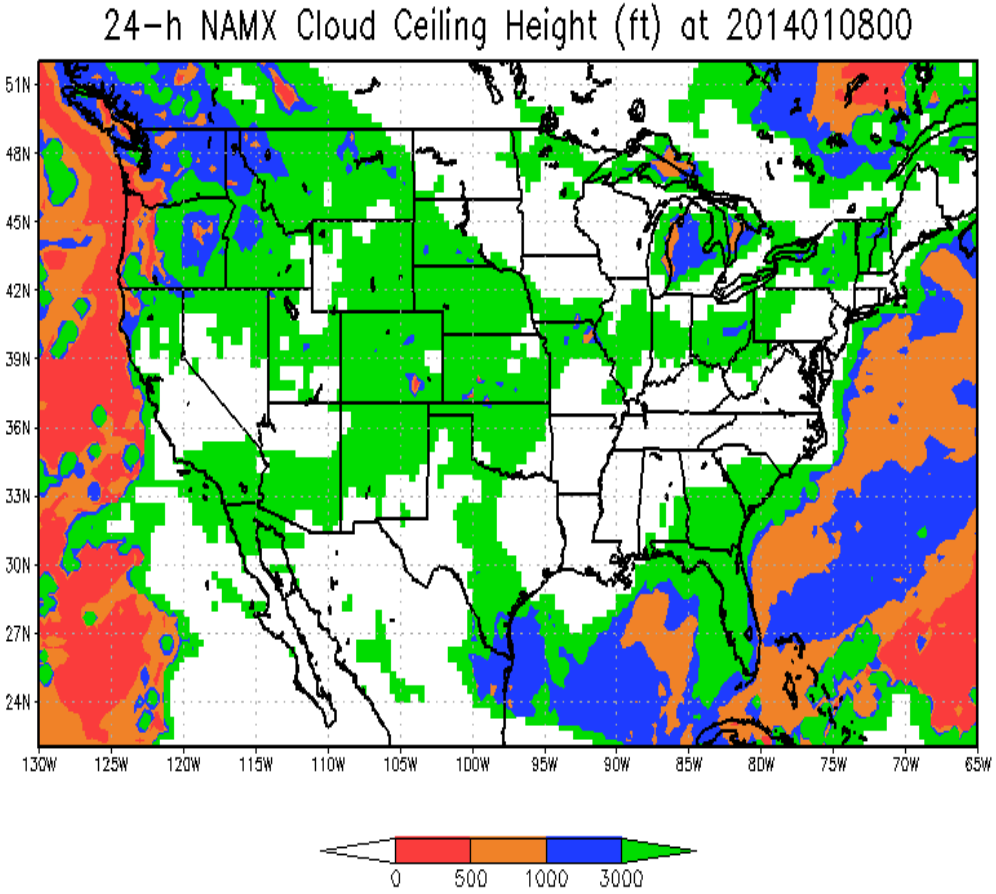
NAM-4 (parallel is blue)



- **Pll CONUS Nest: <u>higher</u> cloud-base height biases compared to Ops CONUS Nest for most hours**
- **Pll CONUS Nest: similar RMSEs for all hours (not shown)**

Winter Example of Cloud Ceiling Height Forecasts





1. **Cloud ceiling heights are too low in ops NAM during snowfall.**
2. **Too much low clouds off the west coast in pll NAM.**

Cloud Ceiling Height Forecasts

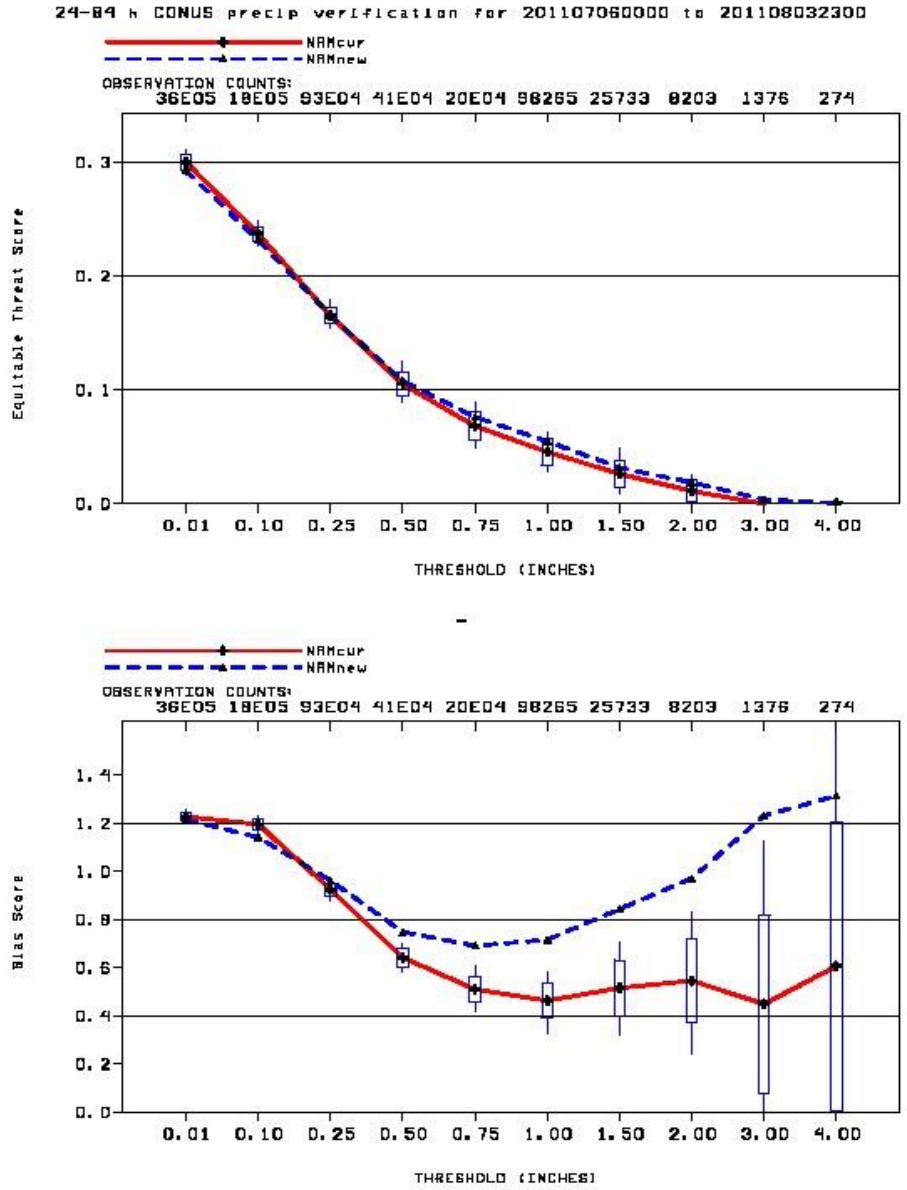
- **Relevant changes in the parallel NAM post.**
  - **Cloud mixing threshold for cloud base + ceiling heights was decreased from 0.001 g/kg in the NAM to 0.01 g/kg in the NAMX.**
  - **Removed the effects of falling snow from calculating cloud base + ceiling heights. Ceiling heights will no longer drop to the surface during snowfall.**
  - **Neither change should lead to lower cloud ceilings in pll NAM.**
- **Larger areas of early morning fog & low clouds in Pll NAM have been an ongoing struggle.**
  - **Possible model changes responsible for this behavior are listed later, has been difficult to resolve.**
  - **Also struggling with 2-m cool, moist biases during day in winter.**

Retrospective testing

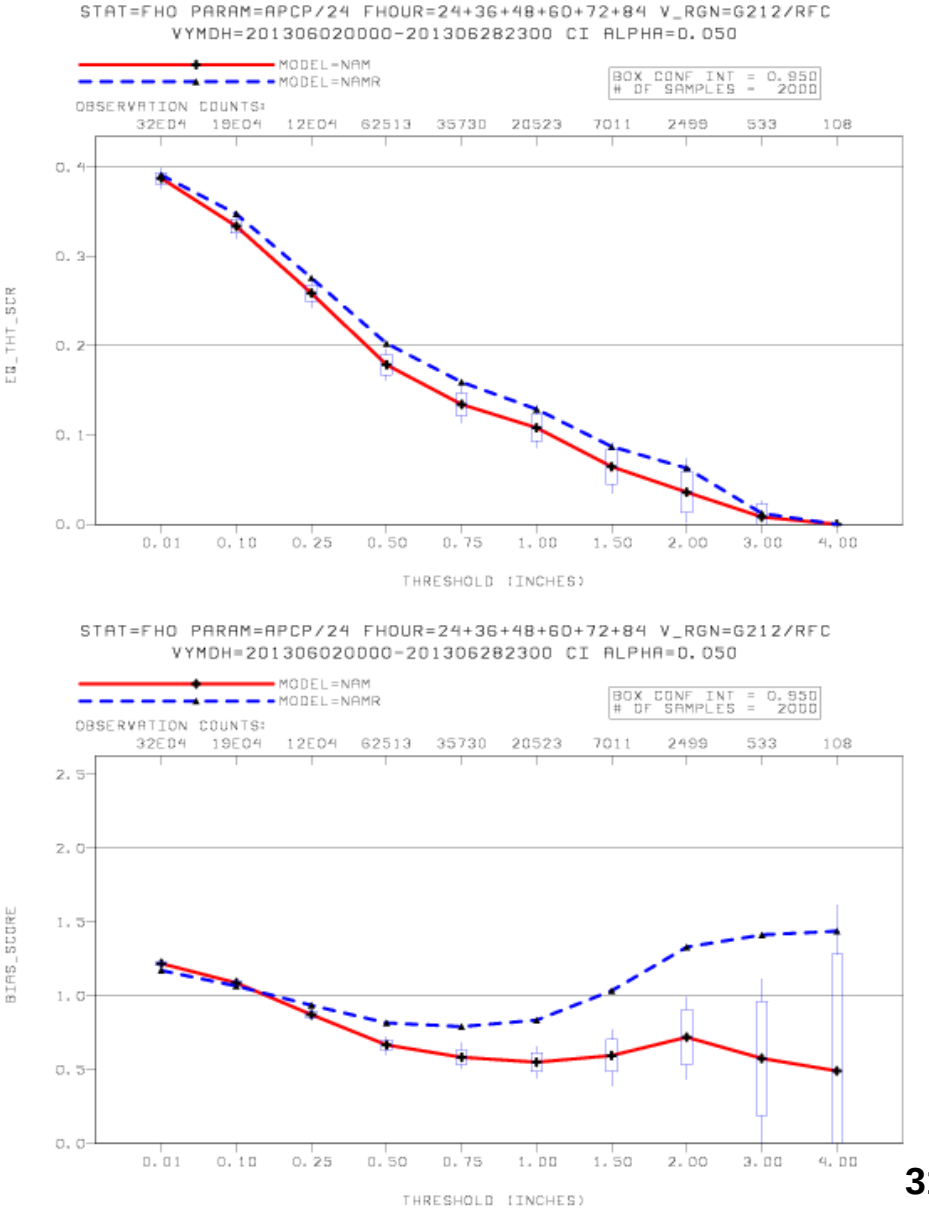
- **Ran NAM-12 parent only to get runs done as quickly as possible, and because primary users of retro output only need NAM-12 files**
- **Three retrospective periods:**
  - **July 2011 : Run at request of AQ group to test CMAQ 4.6.3 off new NAM. Caveat : no global EnKF available (Completed)**
  - **Dec 2012 – Feb 2013 : Cool season retrospective for MDL to tune NAM MOS equations. Caveat : global EnKF only available at 00/06/12/18z valid times, EnKF fcst files valid at 03/09/15/21z were not saved on HPSS until July 2013. (Completed)**
  - **June 2013 – Aug 2013 : Warm season retrospective for NAM MOS tuning. Same caveat as 2012-13 cool season retro. (In progress, will run beyond scheduled implementation date)**
  - **QPF scores for July 2011 and June 2013 retros similar to this summer (bias closer to one at higher thresholds than current ops)**

Warm Season Retrospectives : NAM-12 Control (red) vs Parallel (Blue) QPF scores : ETS (top), Bias (bottom)

July 2011

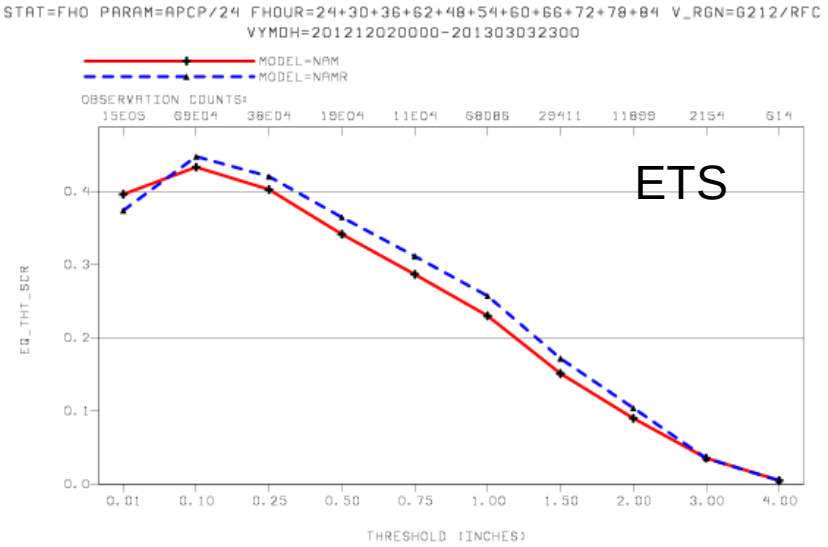


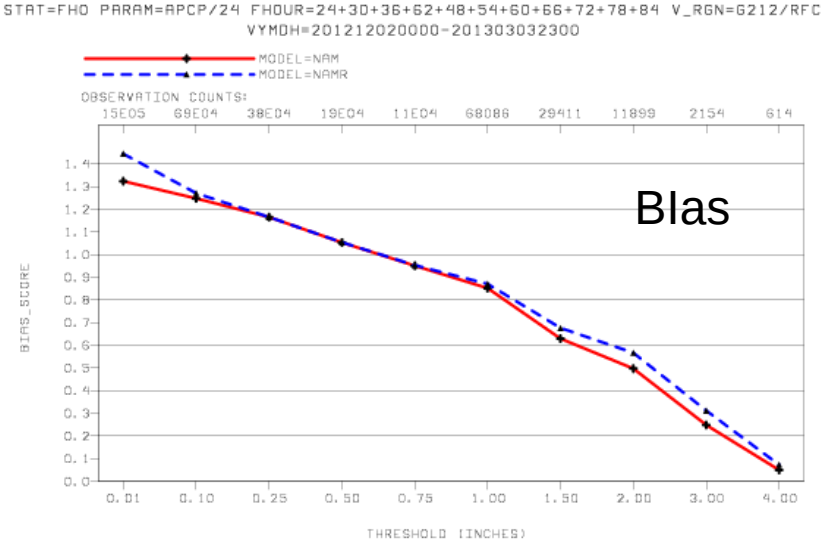
June 2013



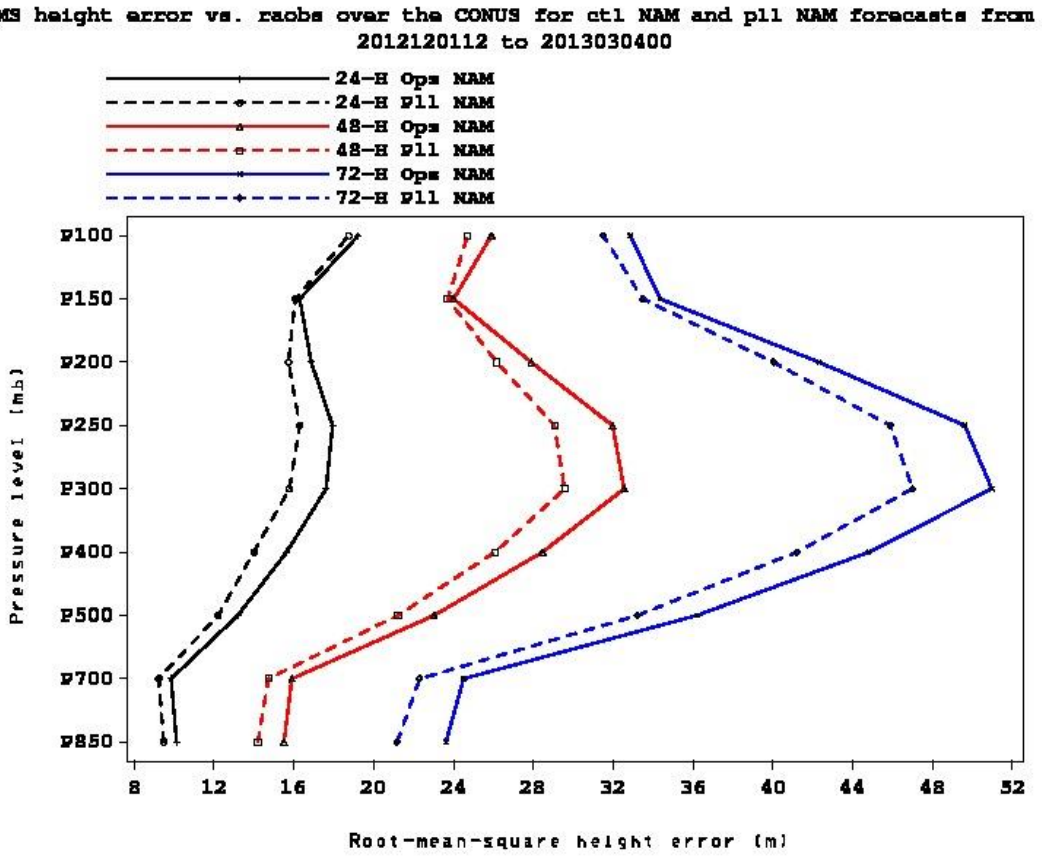
Dec 2012-Feb 2013 period

Modest increase in QPF ETS





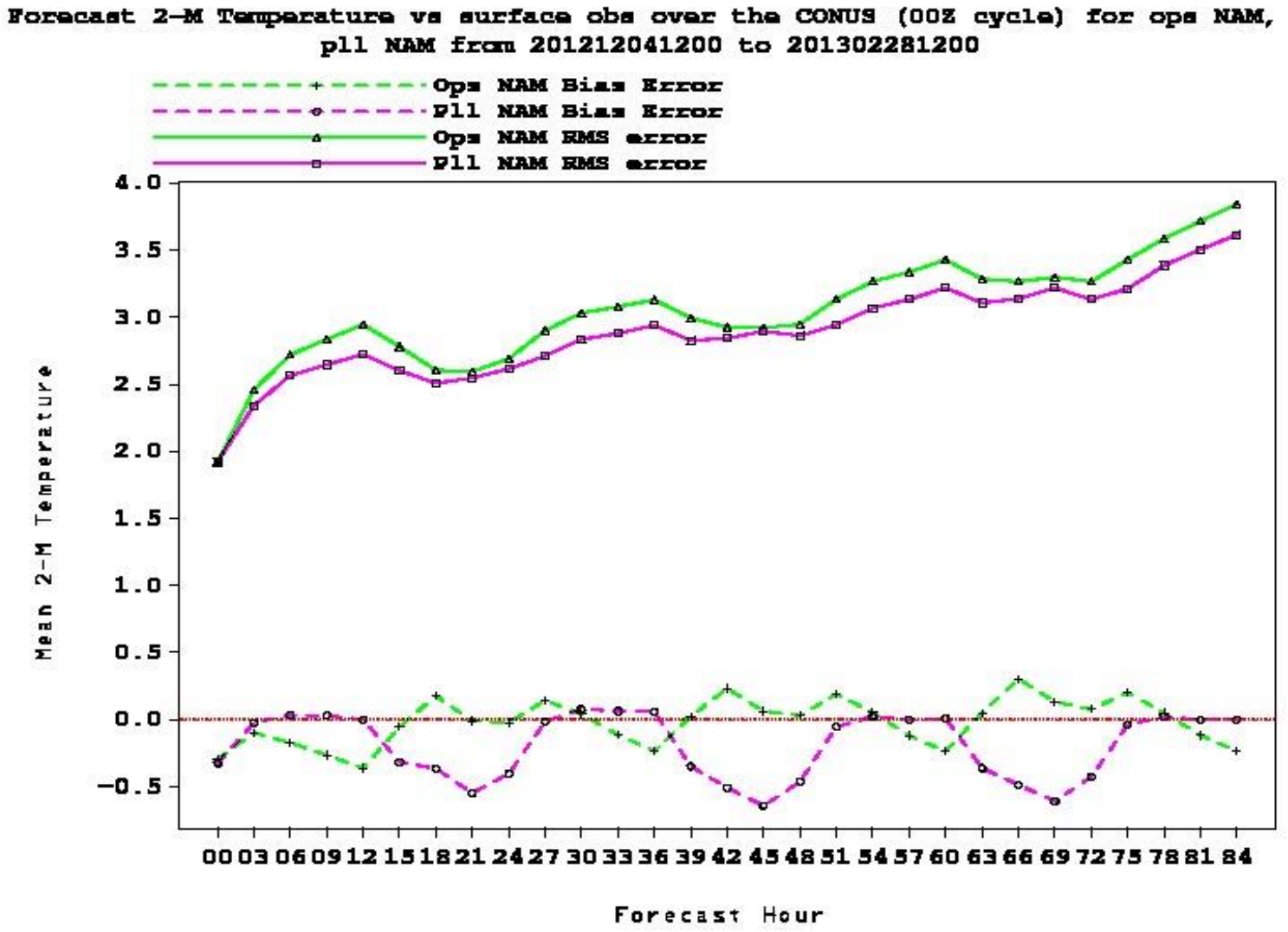
Lower RMS height errors over CONUS



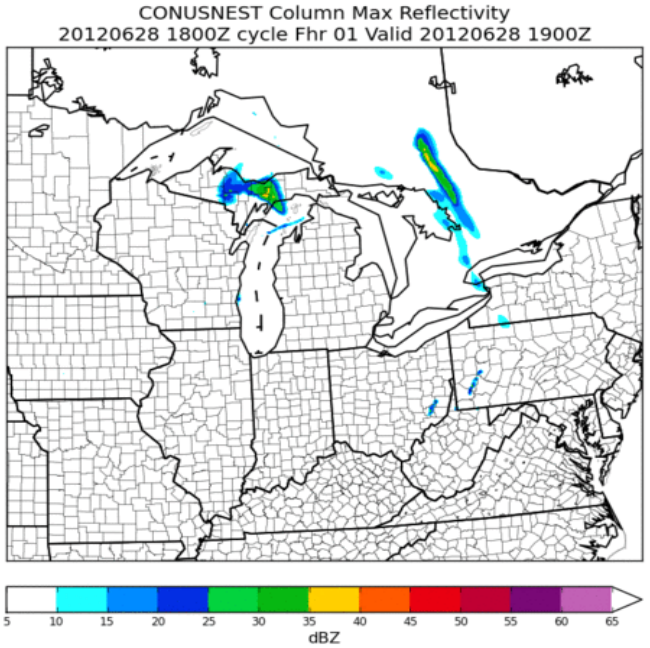
Retro improvement less than real-time run; possibly due to global EnKF forecasts valid at 03/09/15/21z not being archived and thus not used in retro NDAS, whereas they were used in the real-time NDAS parallel

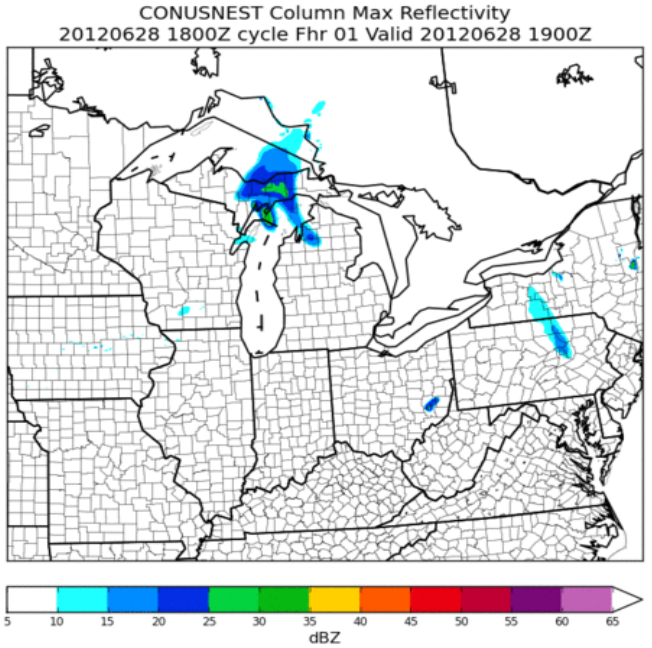
Dec 2012-Feb 2013 period

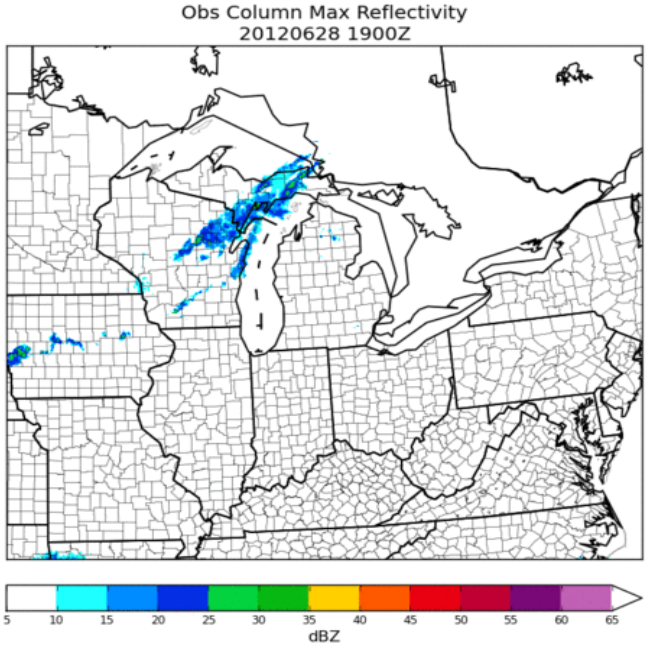
Daytime Cold bias of ~0.5 deg C over CONUS



CONUS 4km rerun for DC Derecho: 18z 6/28/2012 cycle

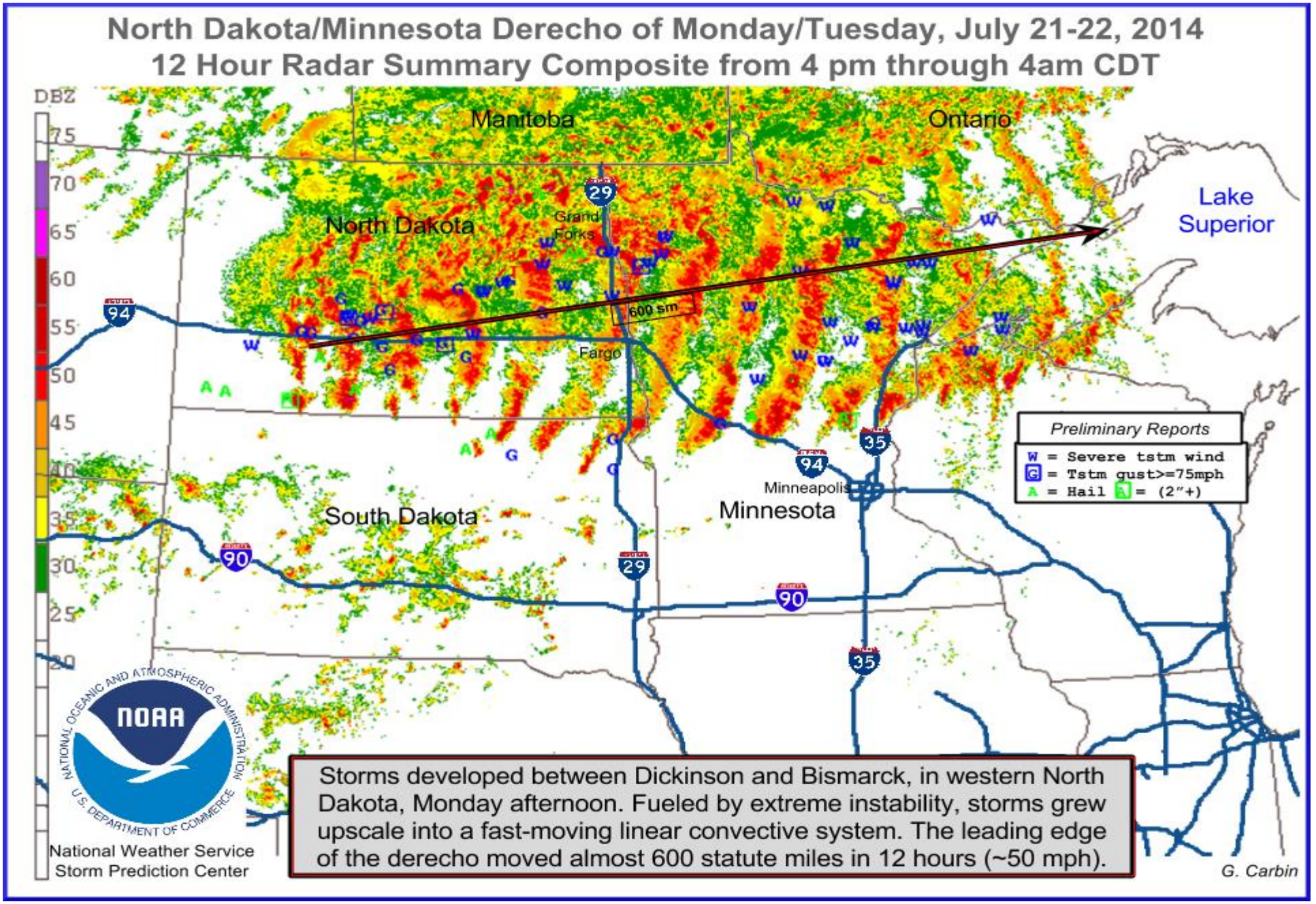




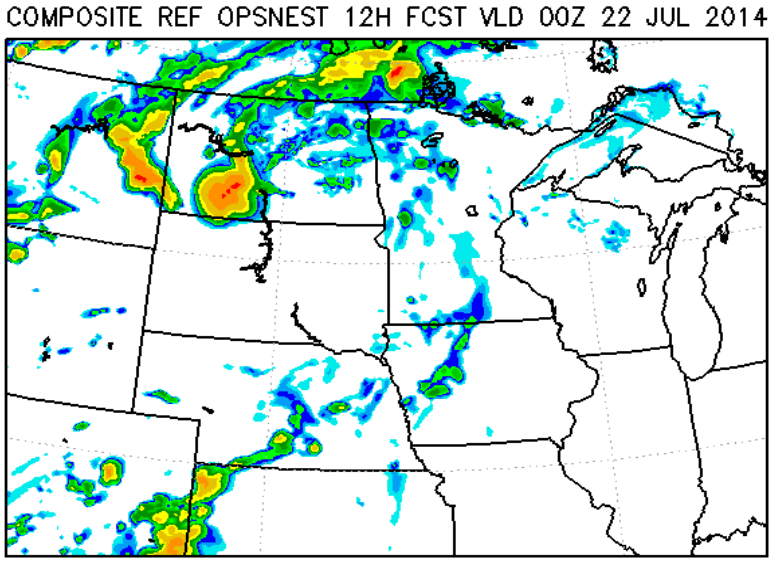


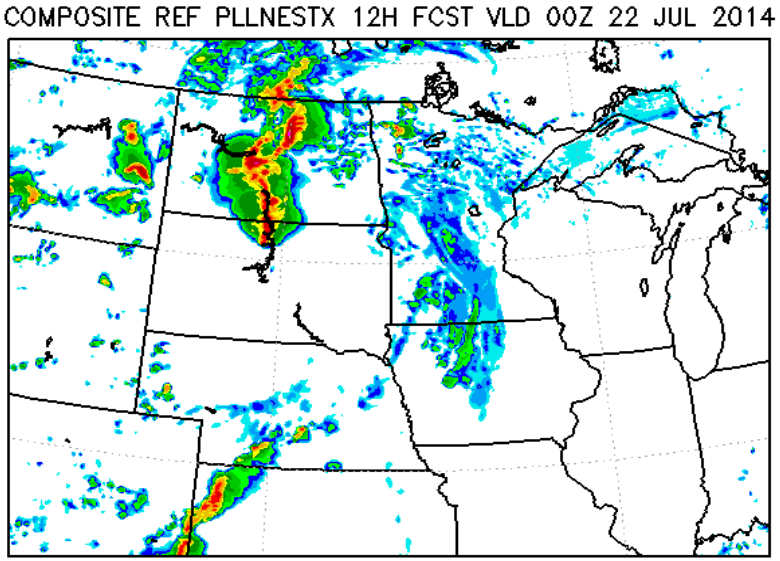
- **Top left : Parallel CONUS 4 km column max reflectivity**
- **Top right : Ops CONUS 4 km column max reflectivity**
- **Bottom left : Observed column max reflectivity**

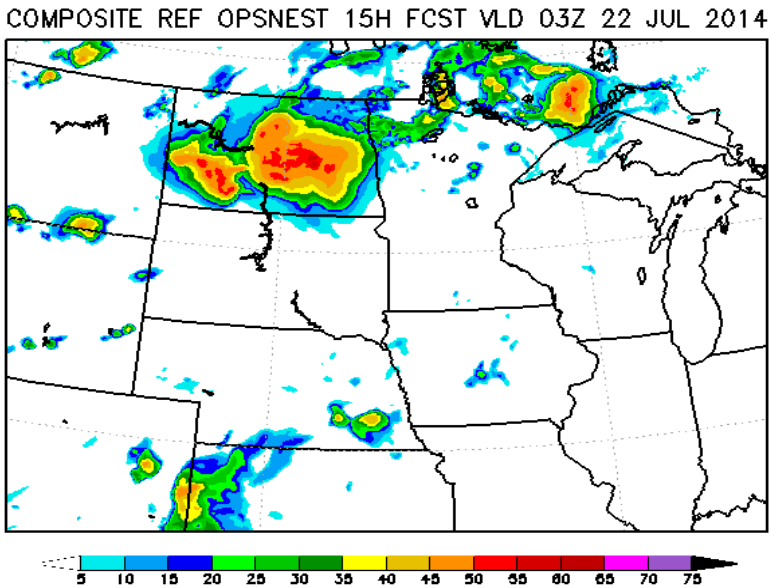
21-22 July ND/MN Derecho

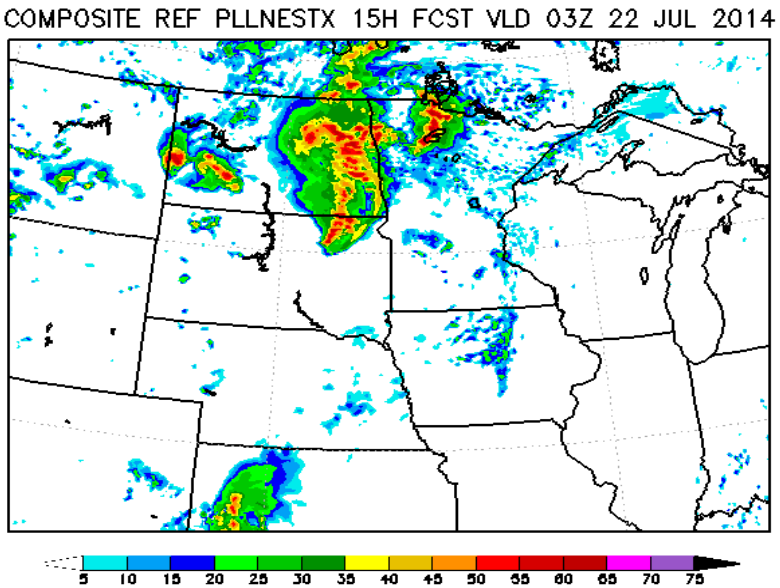


12z 21 July ops vs pll NAM 4km nest : Composite reflectivity

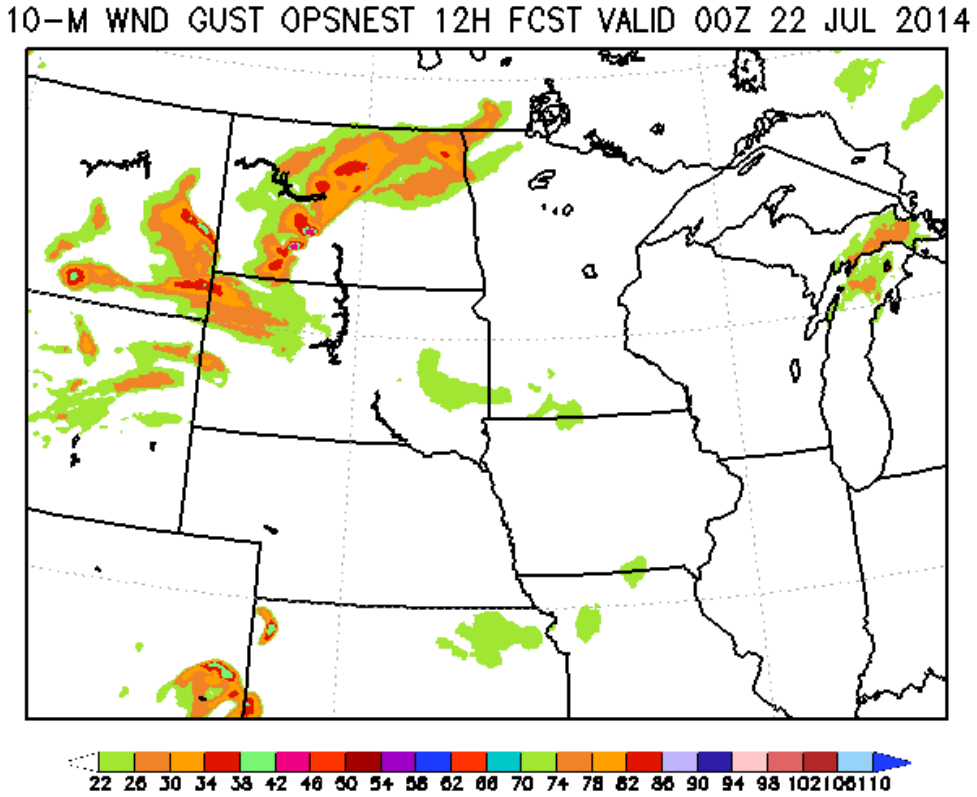


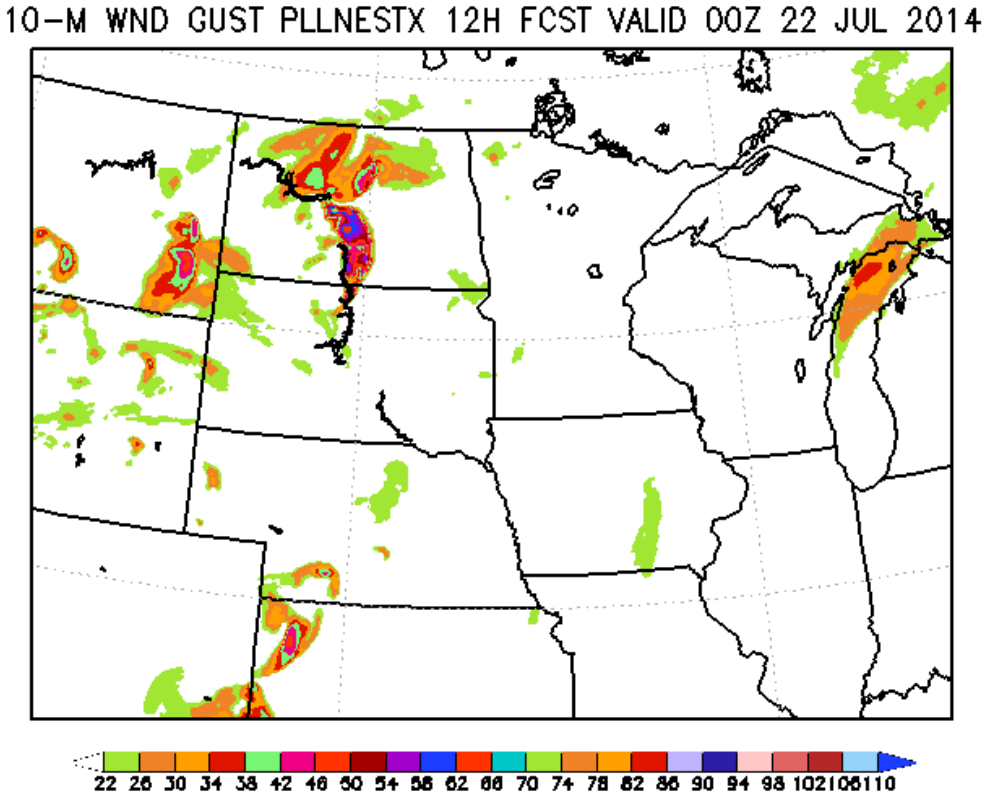






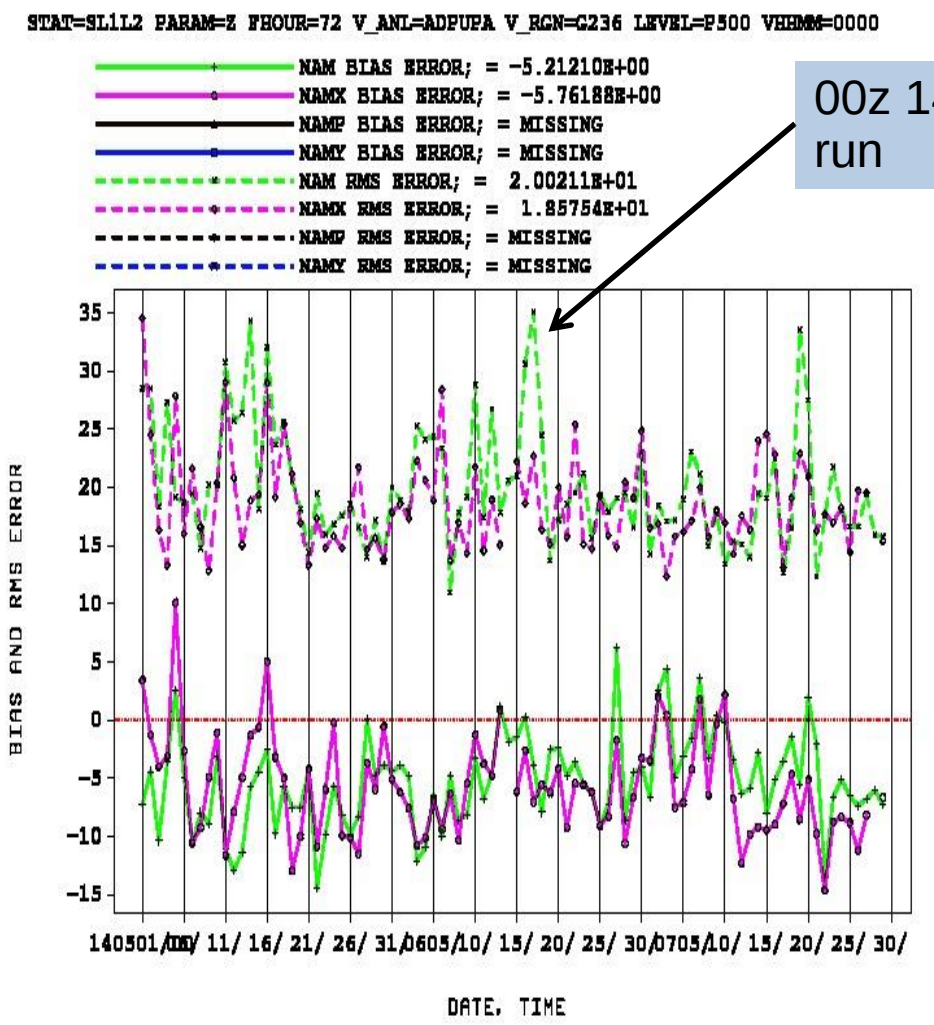
12z 21 July ops vs pll NAM 4km nest : 10-m Wind Gust speed





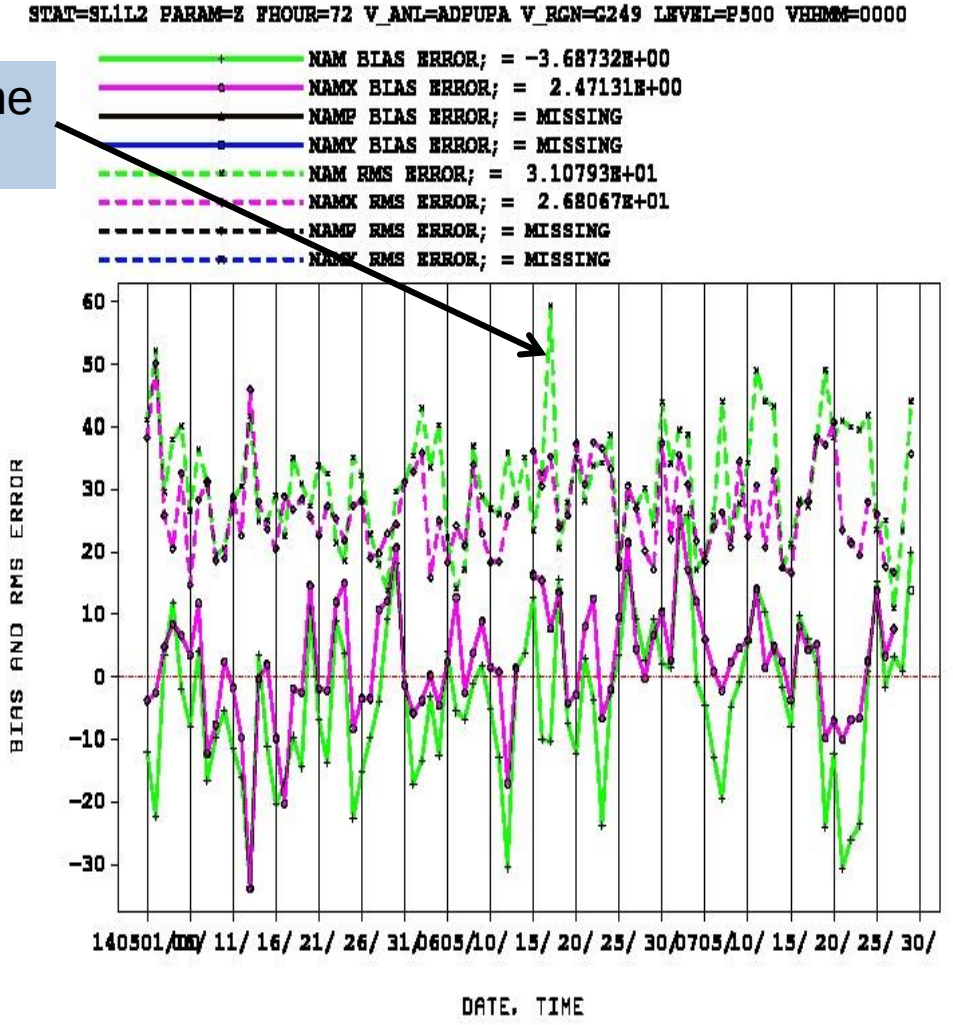
Time series of day 3 500 mb RMS (dashed lines)/bias (solid lines) error over CONUS/AK: 1 May – 29 July 2014

00z cycle over CONUS;
Ops=Green, Pll=Magenta

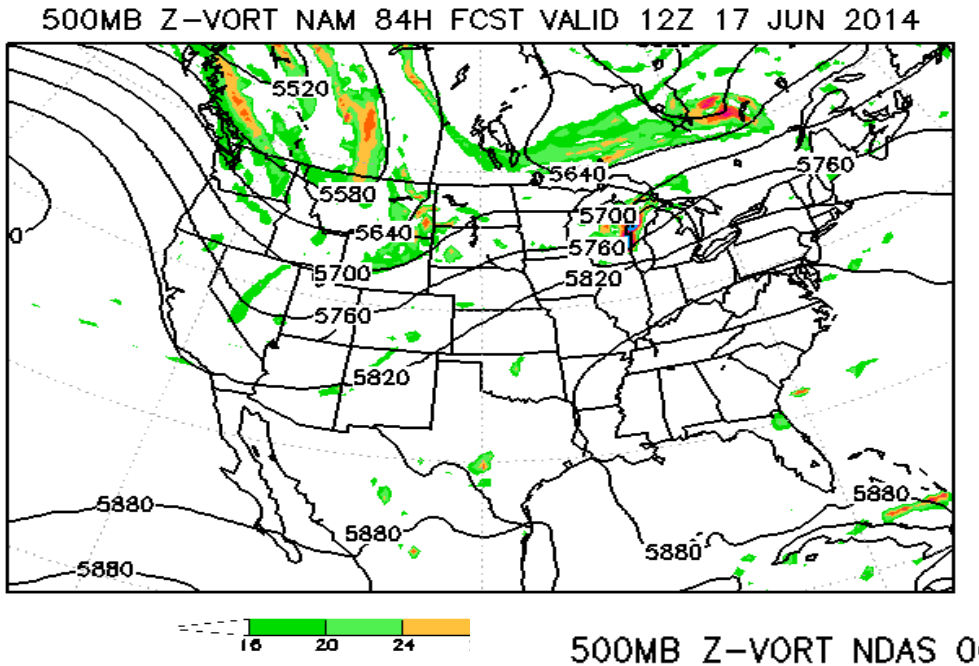


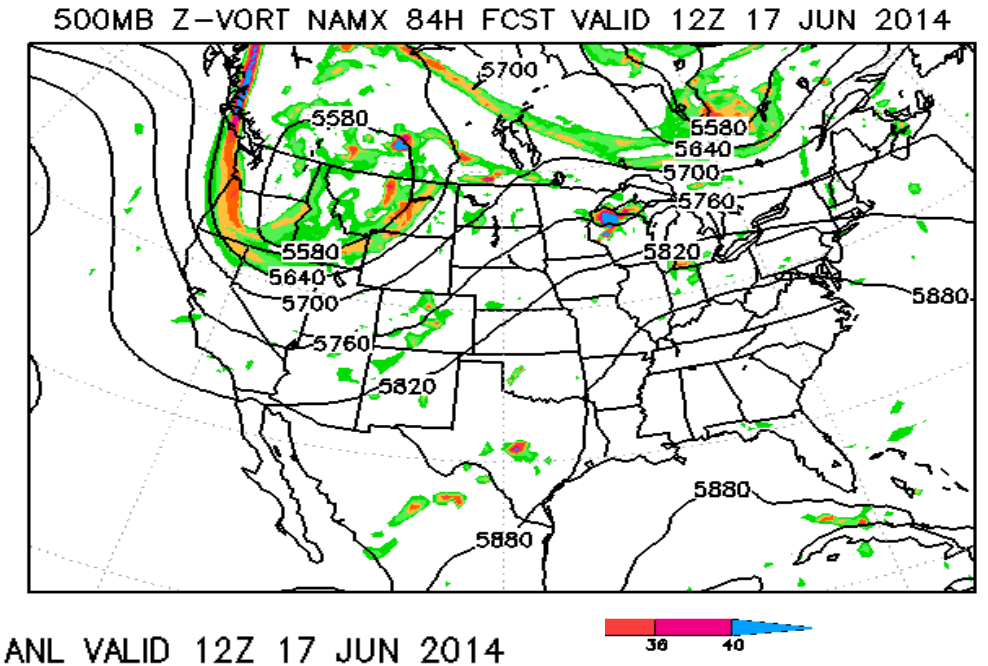
00z 14 June run

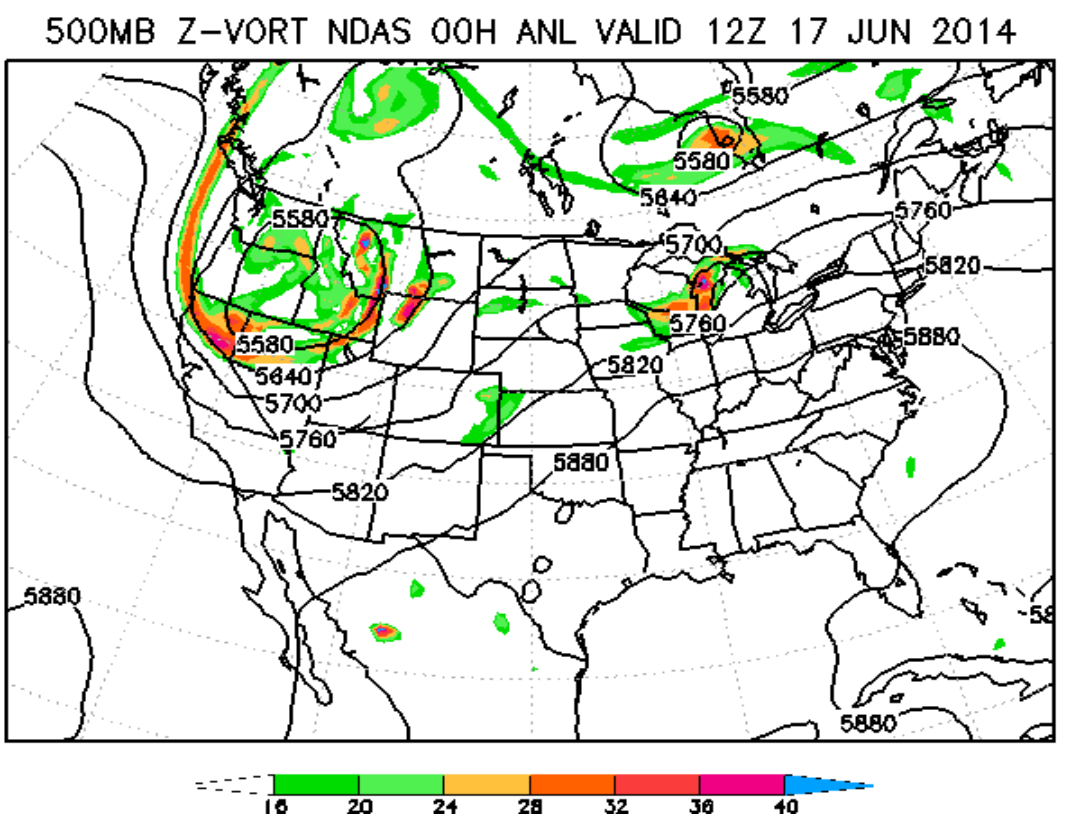
00z cycle over Alaska;
Ops=Green, Pll=Magenta



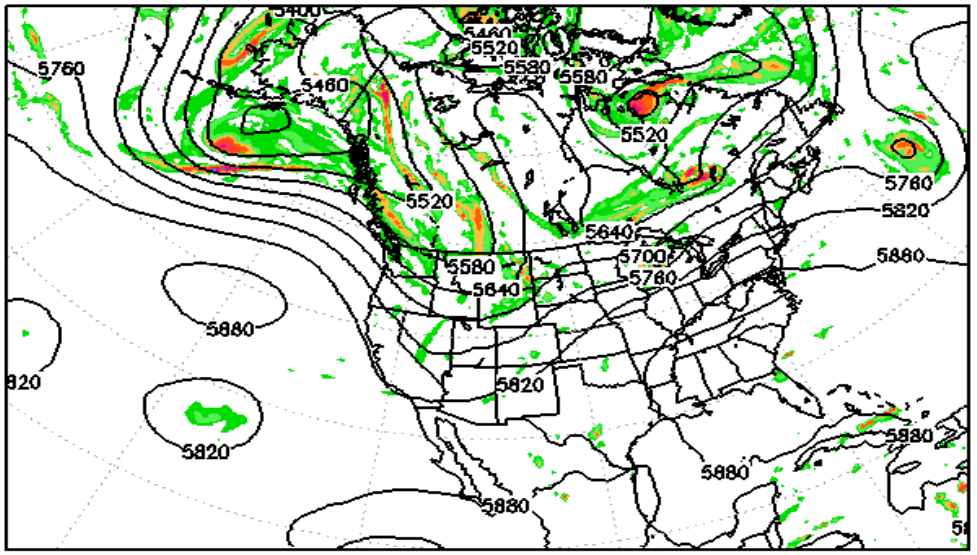
00z 6/14 NAM vs NAMX at 84-h



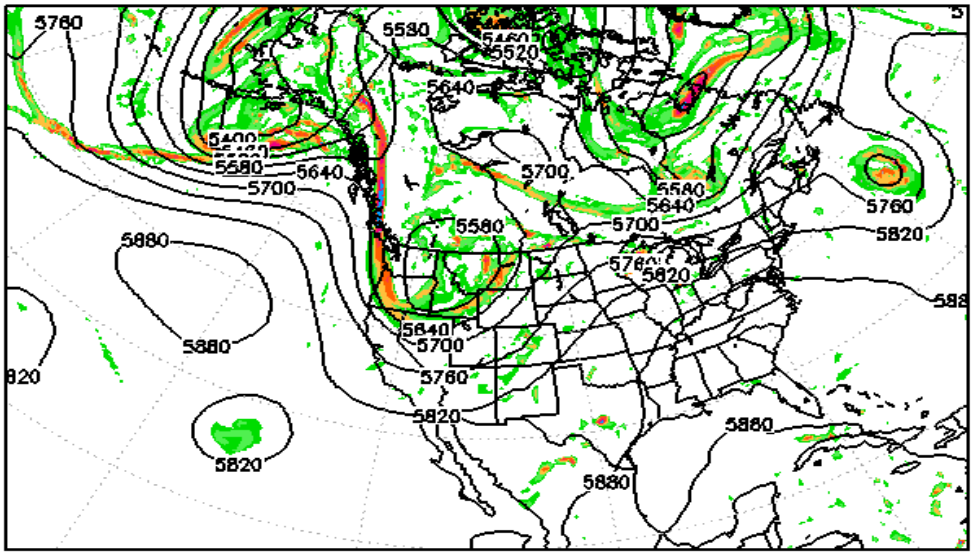


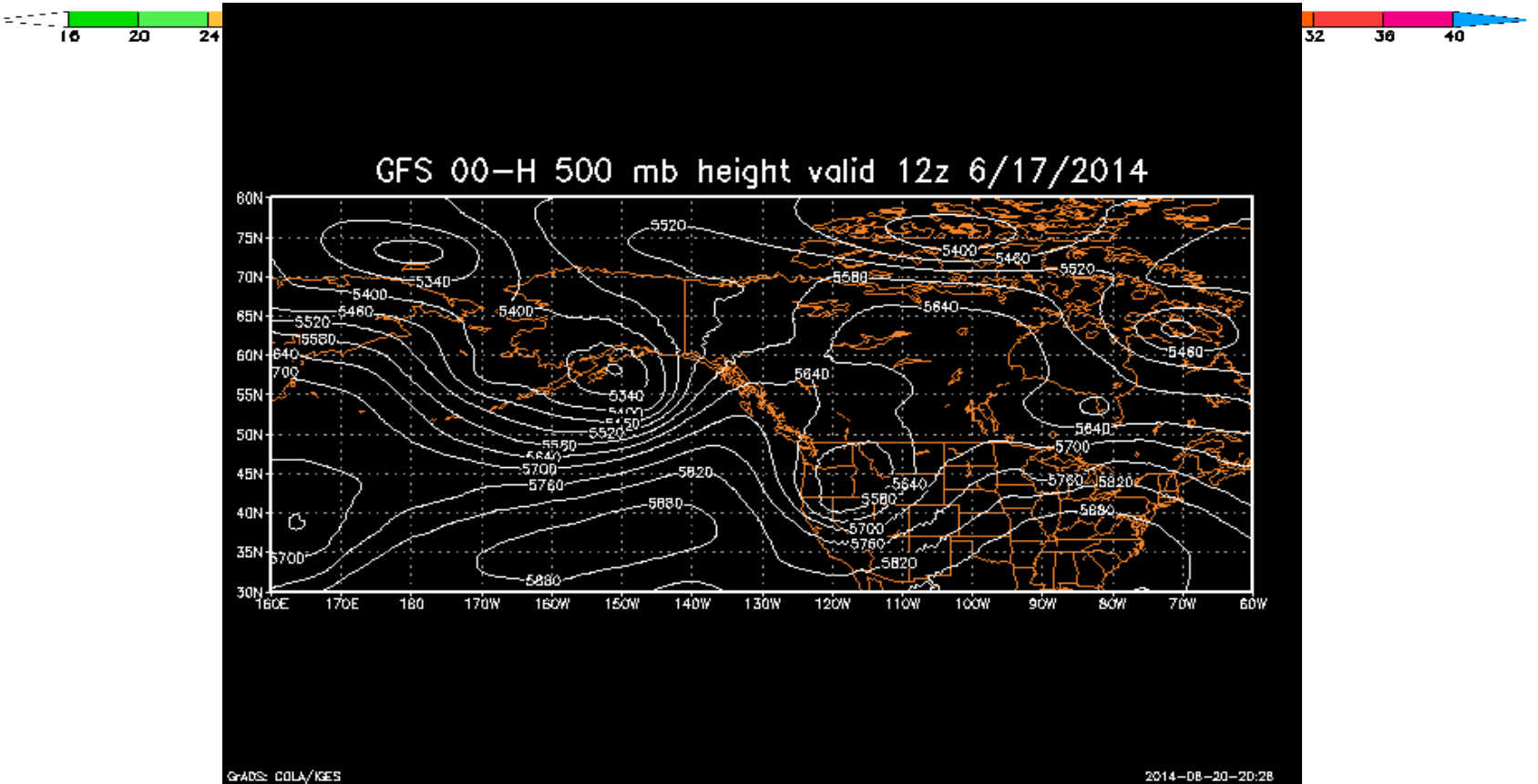


500MB Z-VORT NAM 84H FCST VALID 12Z 17 JUN 2014



500MB Z-VORT NAMX 84H FCST VALID 12Z 17 JUN 2014





GFS 00-H 500 mb height valid 12z 6/17/2014

GrADS: COLA/IGES

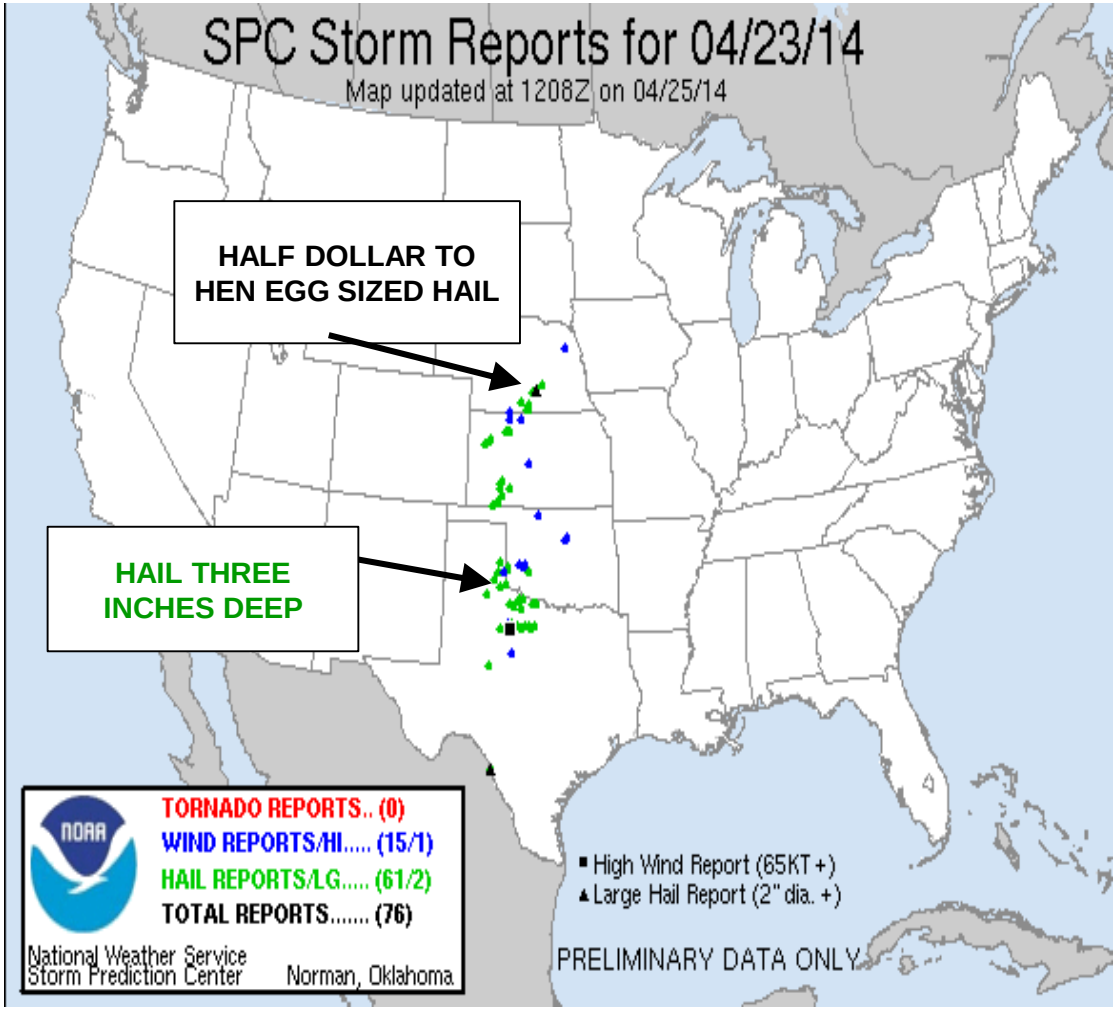
2014-08-20-20:28

Feedback from NWS Anchorage

- **Comments provided by Jim Nelson, acting MIC (email to Chris McGee and myself on 7 August):**
  - **"Operational NAM was inferior to the parallel NAM. Forecasters cannot wait for it to be implemented. They loved the performance of the model"**
  - **"Parallel NAM was able to capture many Easterly Wave events better than any operational model. These easterly waves bring moderate to heavy precip events to Southeast and South Central Alaska and are a flood indicator. The parallel NAM in these cases was particularly well in handling speed of the events."**
  - **"In other cases, QPF was a bit better in placement and intensity"**
- **From Shaun Baines, forecaster at NWS Anchorage (email to J. Carley on 23 June)**
  - **"The Operational NAM has really struggled of late with handling of the many closed upper level lows (and embedded short-waves rotating around them) we get this time of year. All of the models tend to struggle with these, but the NAM is often the outlier among all of the available models and only seems to get in line with the correct solution at about 24 hrs out. Some forecasters are looking at the Parallel NAM and it is doing a MUCH [*sic*] better job. It is more often grouped together with the other solutions."**

Parallel vs Operational NAM CONUS 4 km Nest : 23-24 April 2014 Severe Weather

Eric Aligo and Brad Ferrier



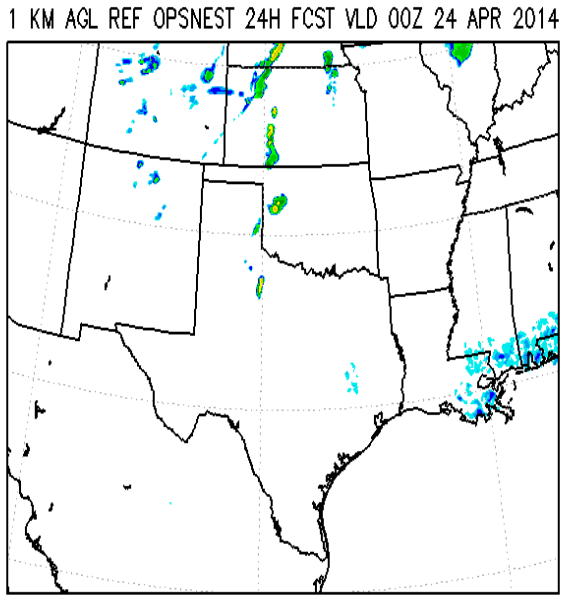
1 km AGL Reflectivity

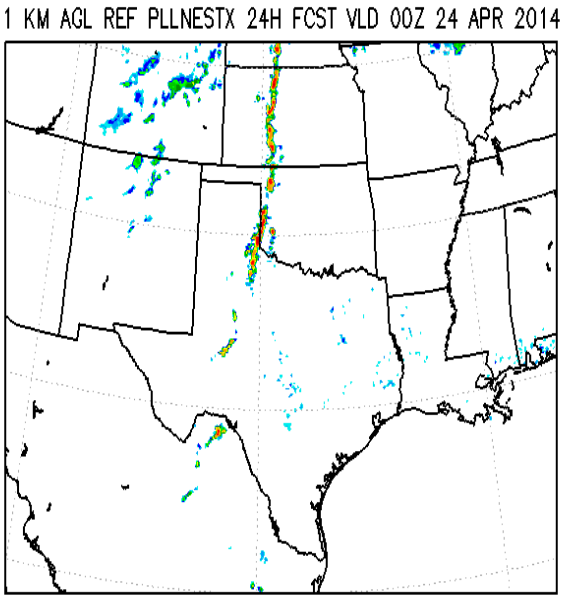
Operational Nest

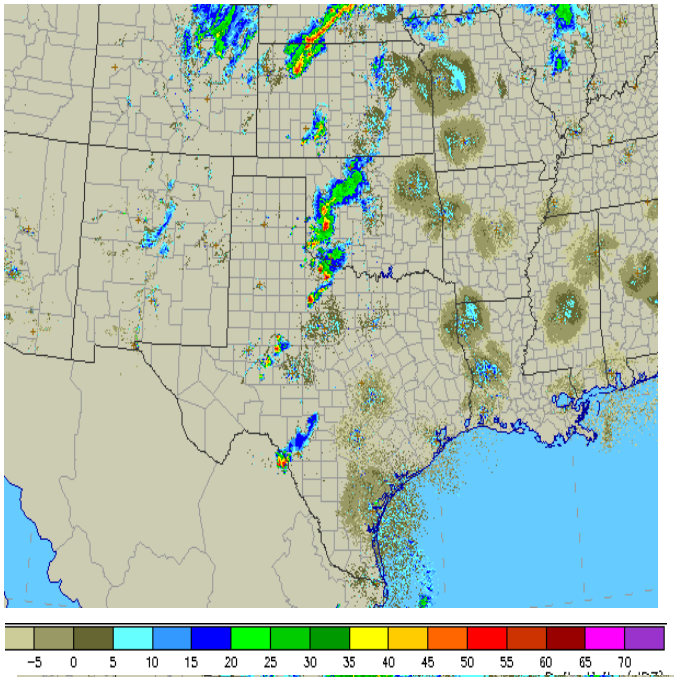
Parallel Nest

0.5 deg Reflectivity

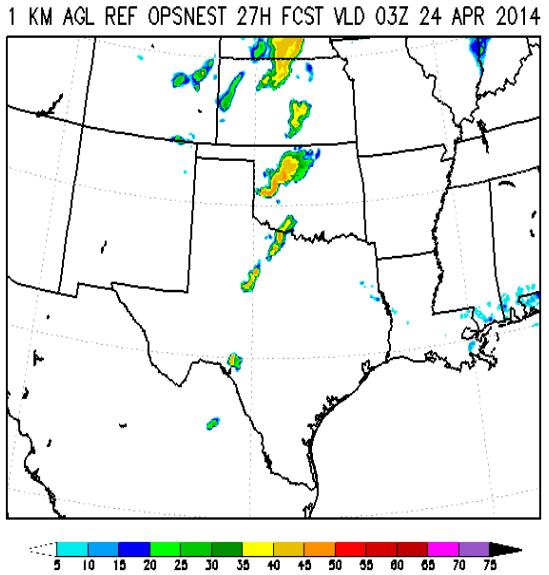
24-h vld 00z 4/24/14

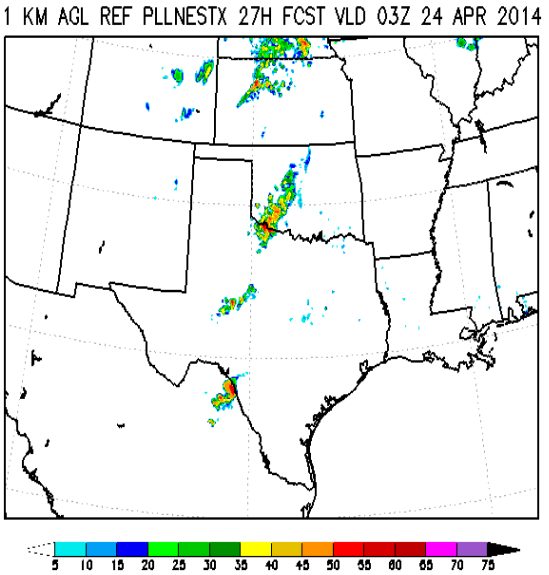


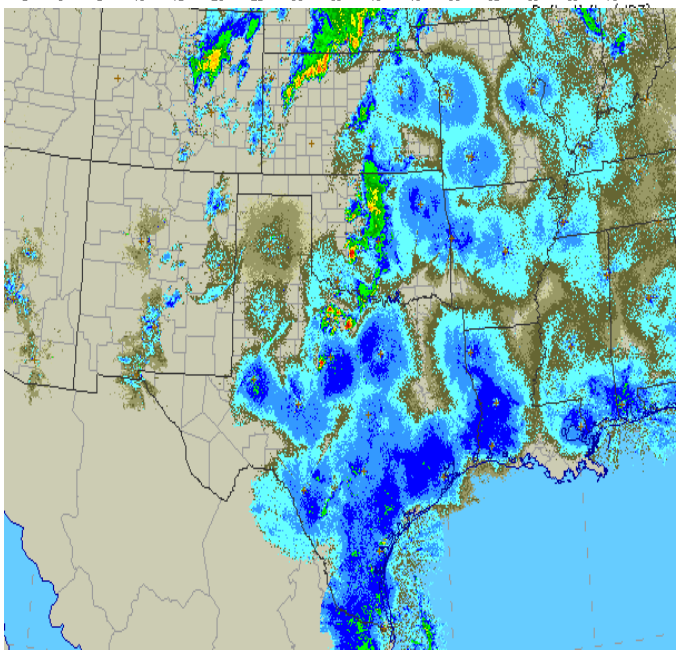




27-h vld 03z 4/24/14





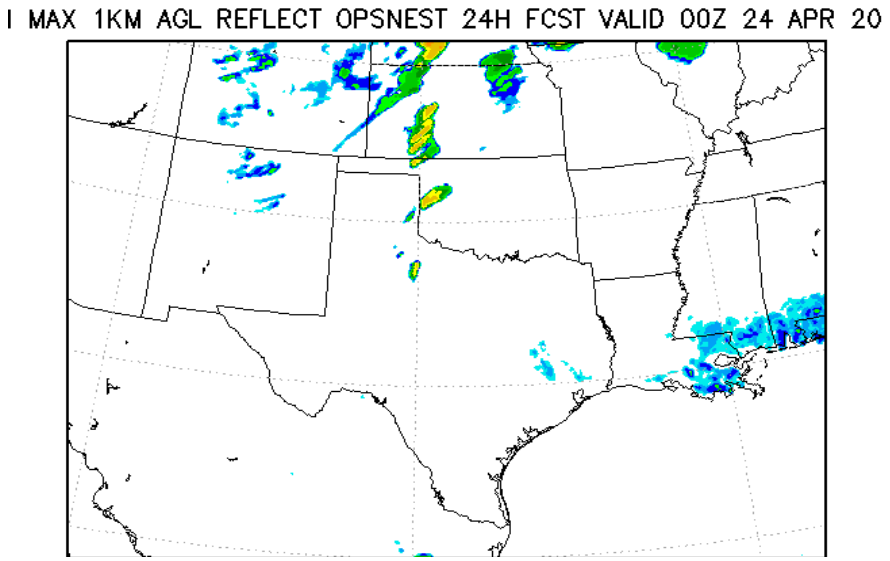


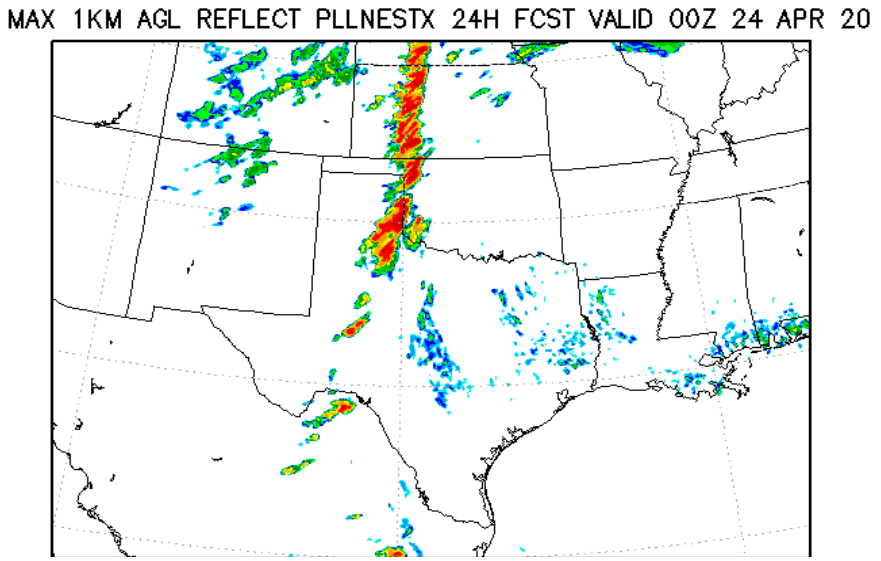
Max hourly 1 km AGL Reflectivity

Operational Nest

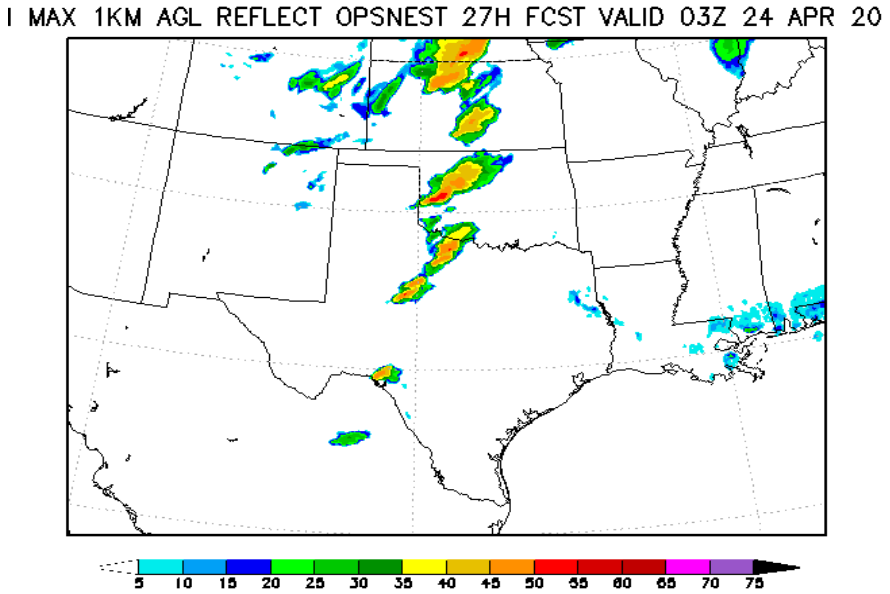
Parallel Nest

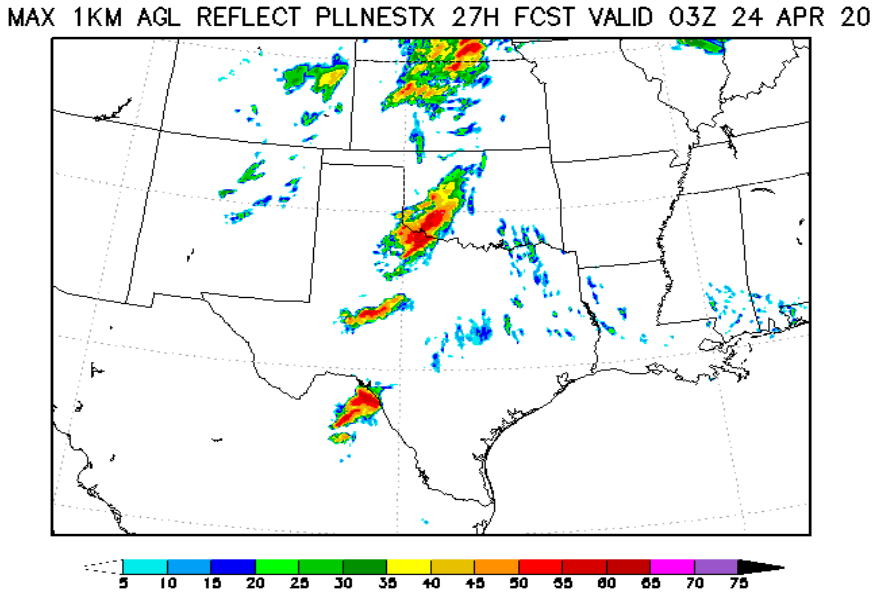
24-h vld 00z 4/24/14





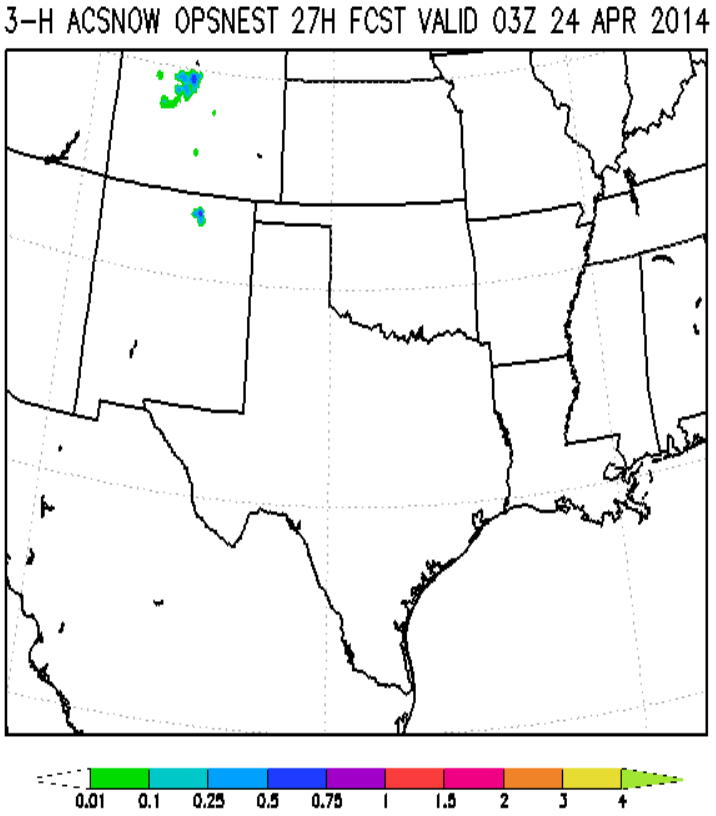
27-h vld 03z 4/24/14



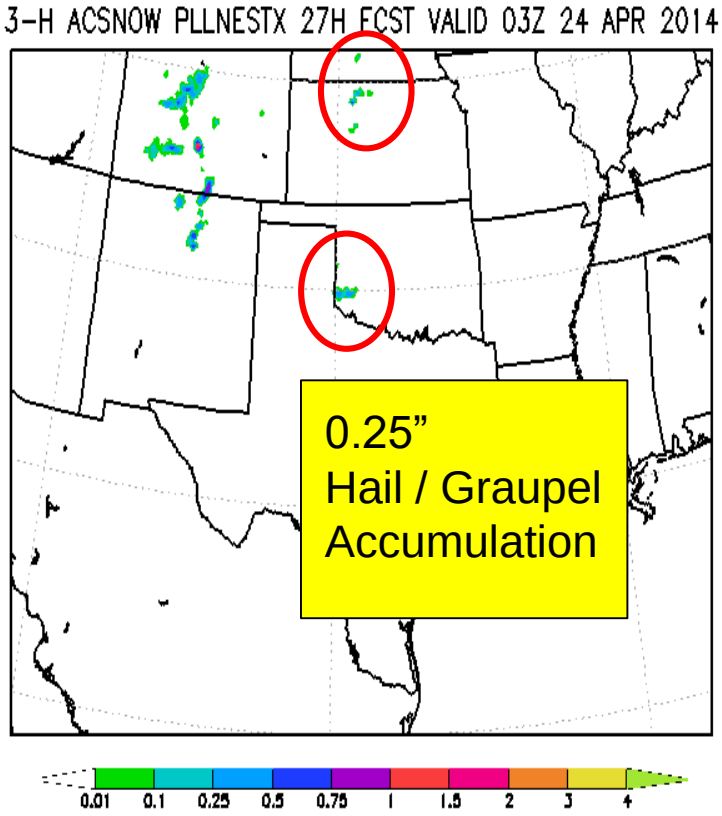


03-h “Snow” (Total Ice) Accumulation

Operational Nest



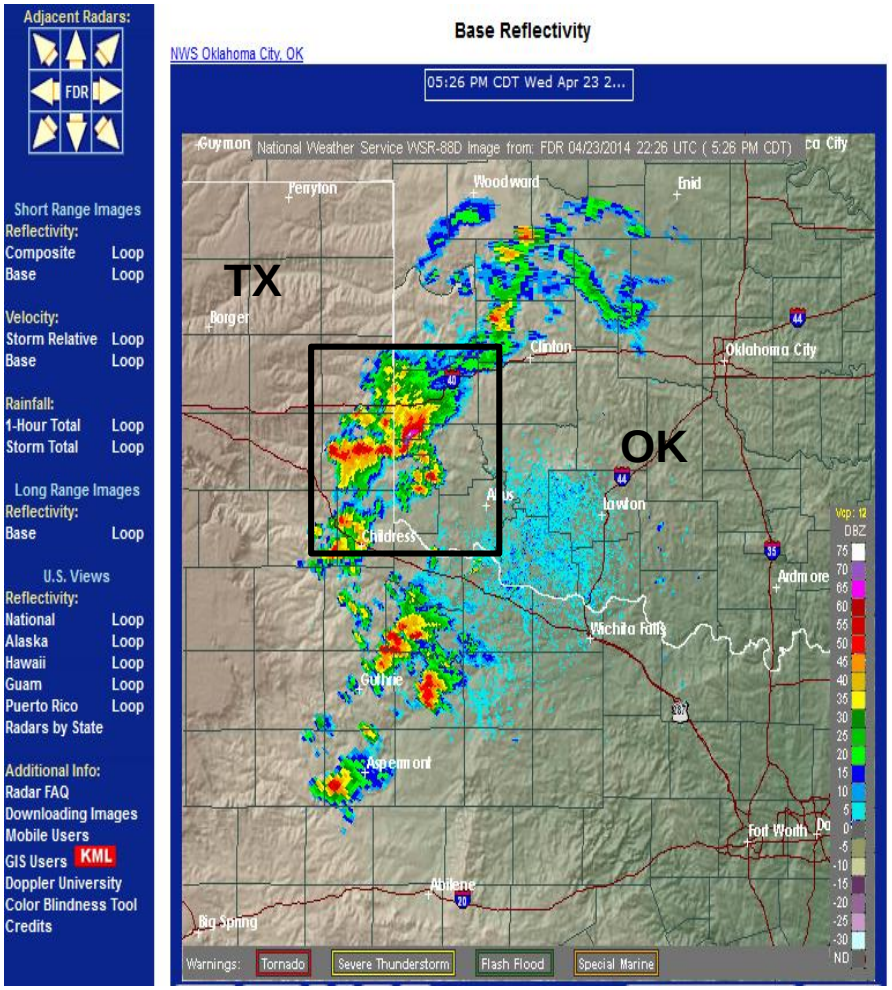
Parallel Nest



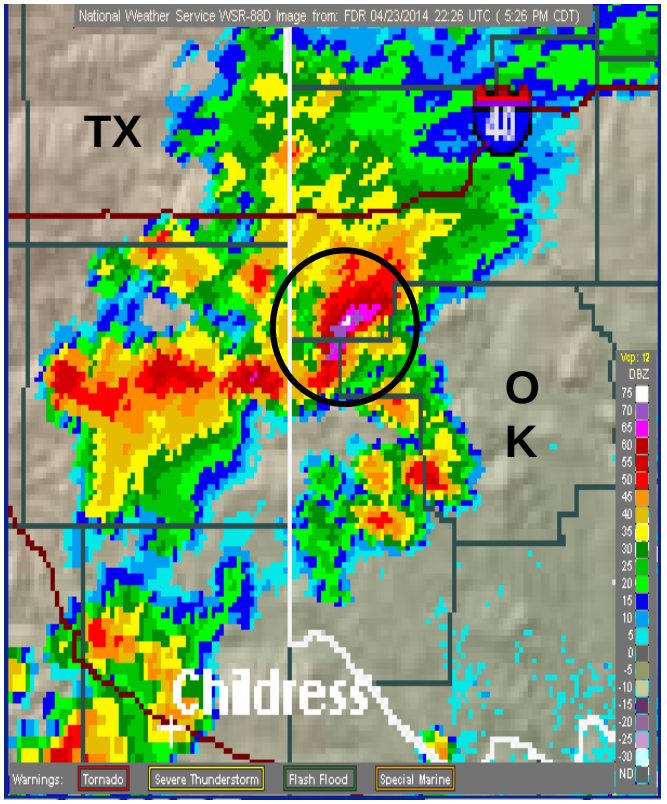
27-h (03 UTC 24 April 2014)

Base Reflectivity

22:26 UTC / 23



Zoomed In

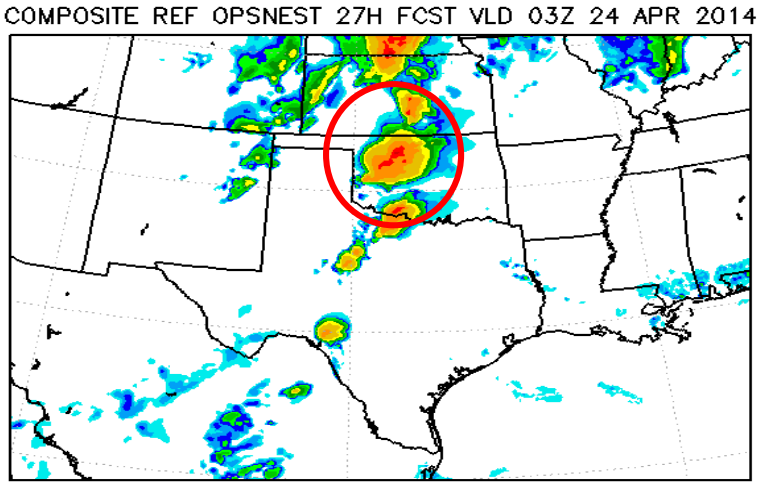


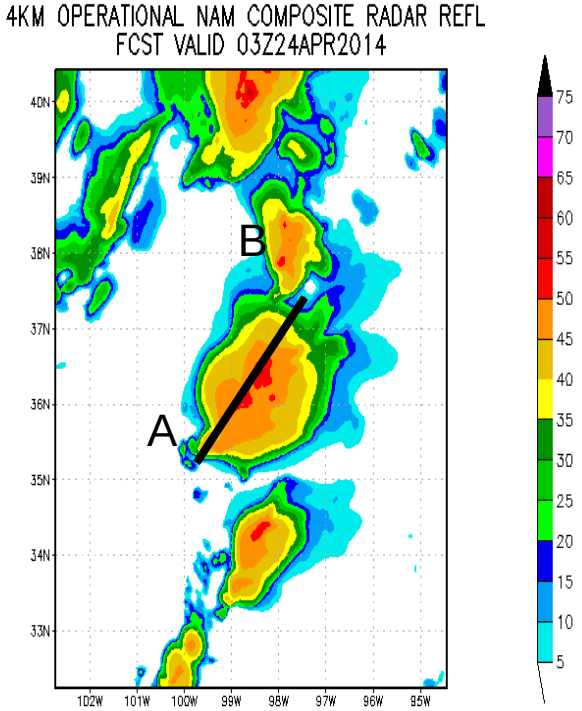
75 dBZ

Composite Reflectivity

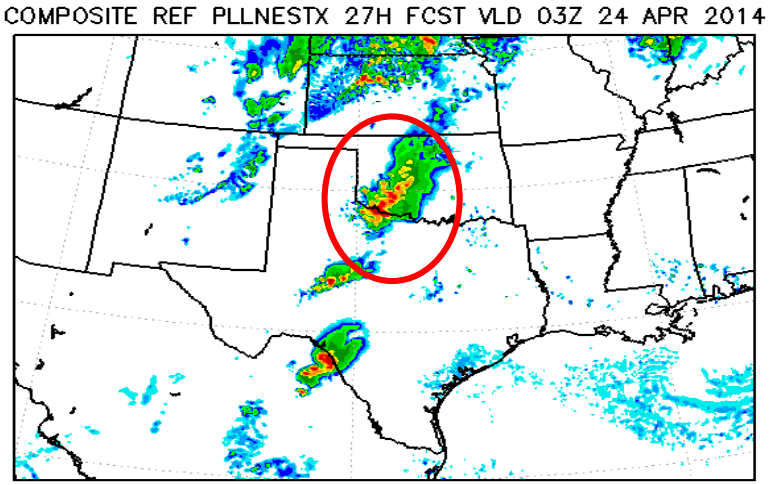
Remaining Slides Focus on Areas Circled

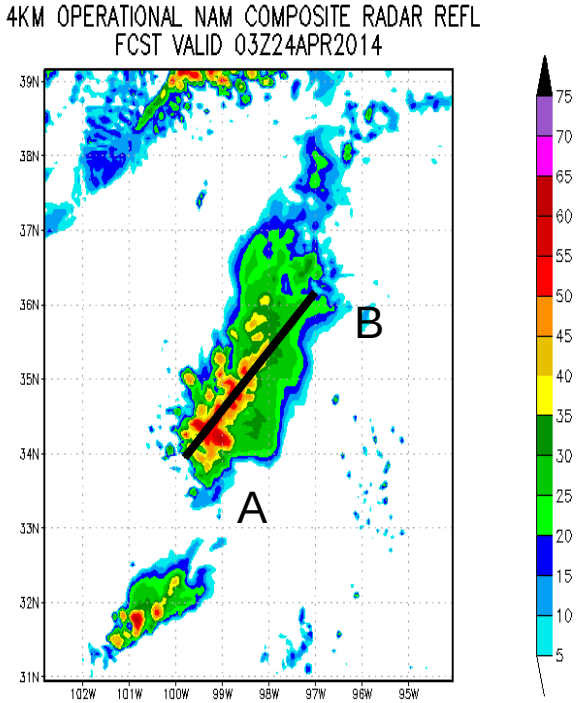
Operational Nest





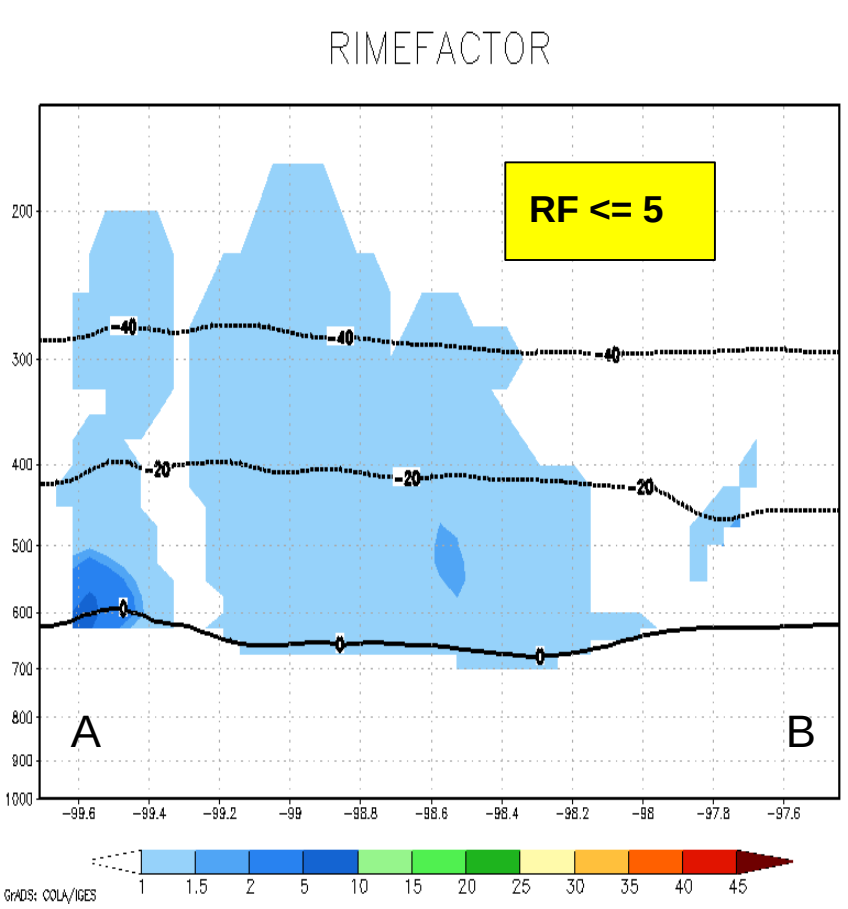
Parallel Nest



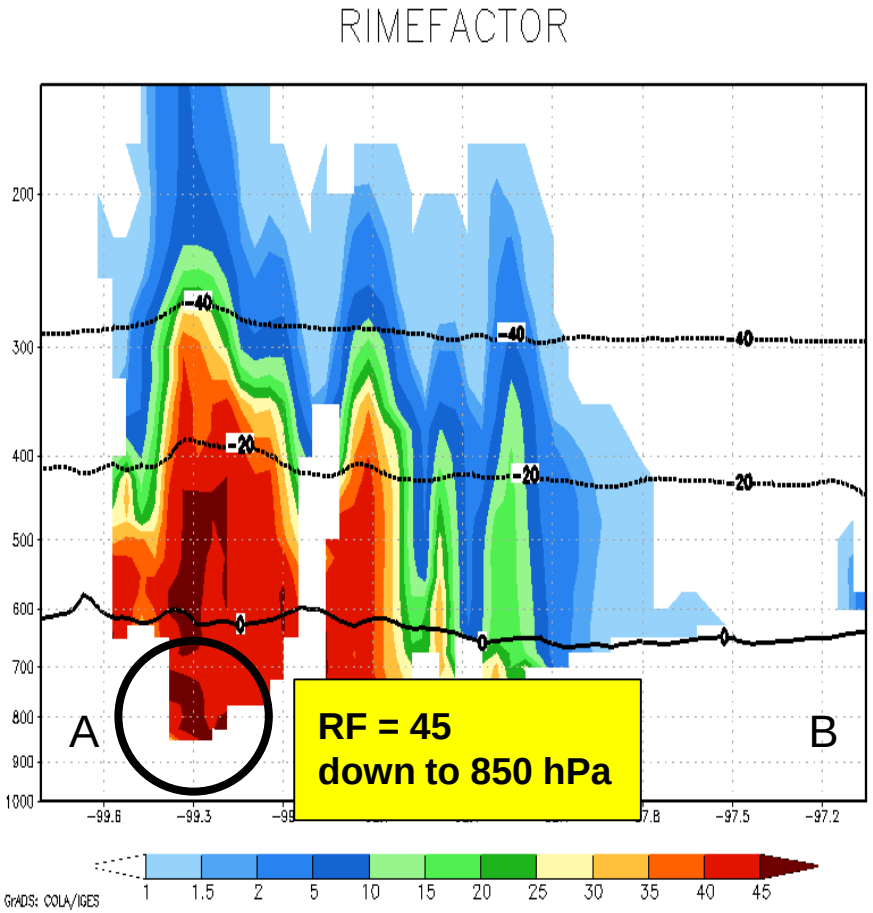


Rime Factor (RF)

Operational Nest



Parallel Nest



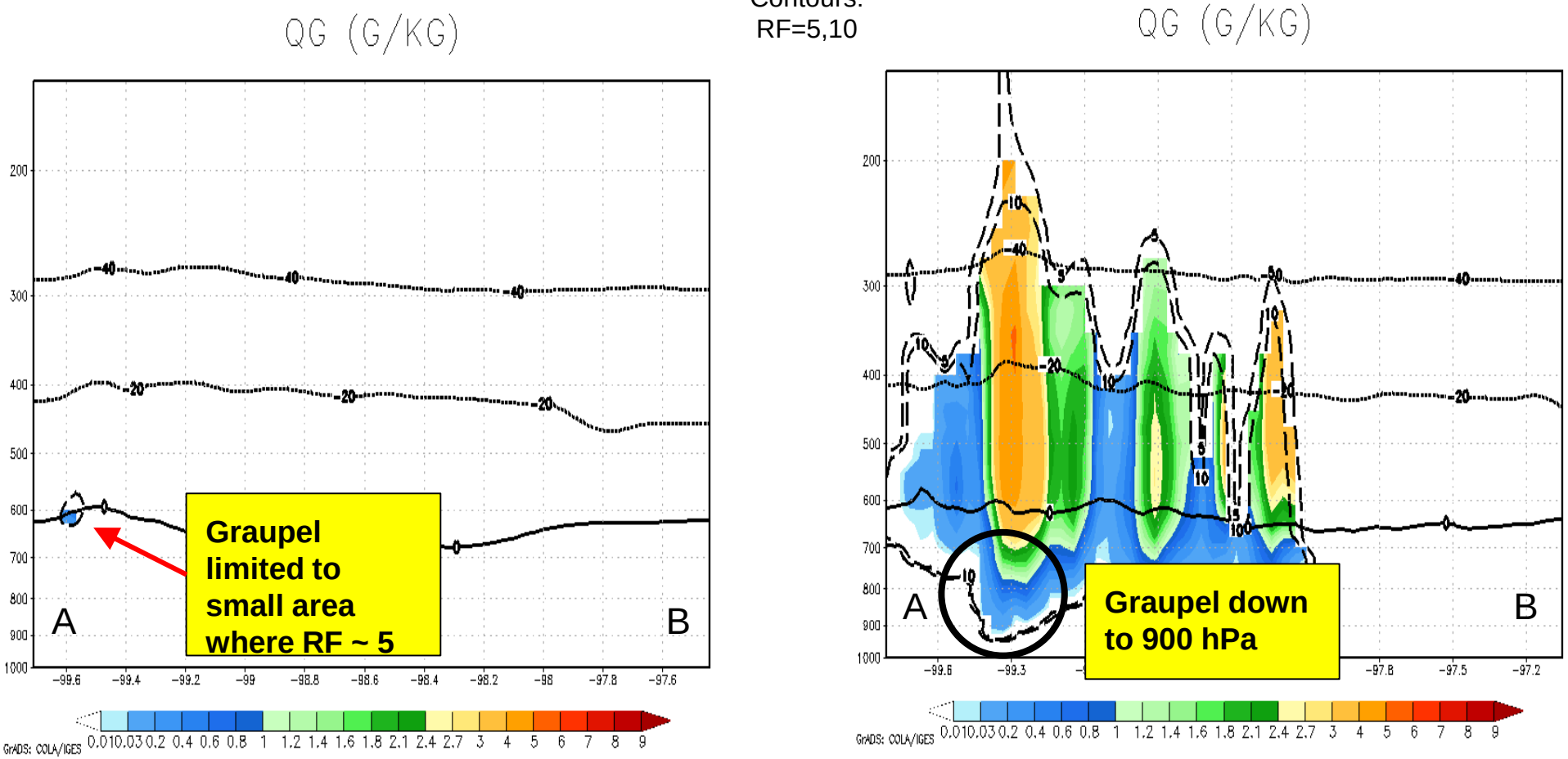
27-h (03 UTC 24 April 2014)

Graupel

Operational Nest

Dashed Contours: RF=5,10

Parallel Nest



27-h (03 UTC 24 April 2014)

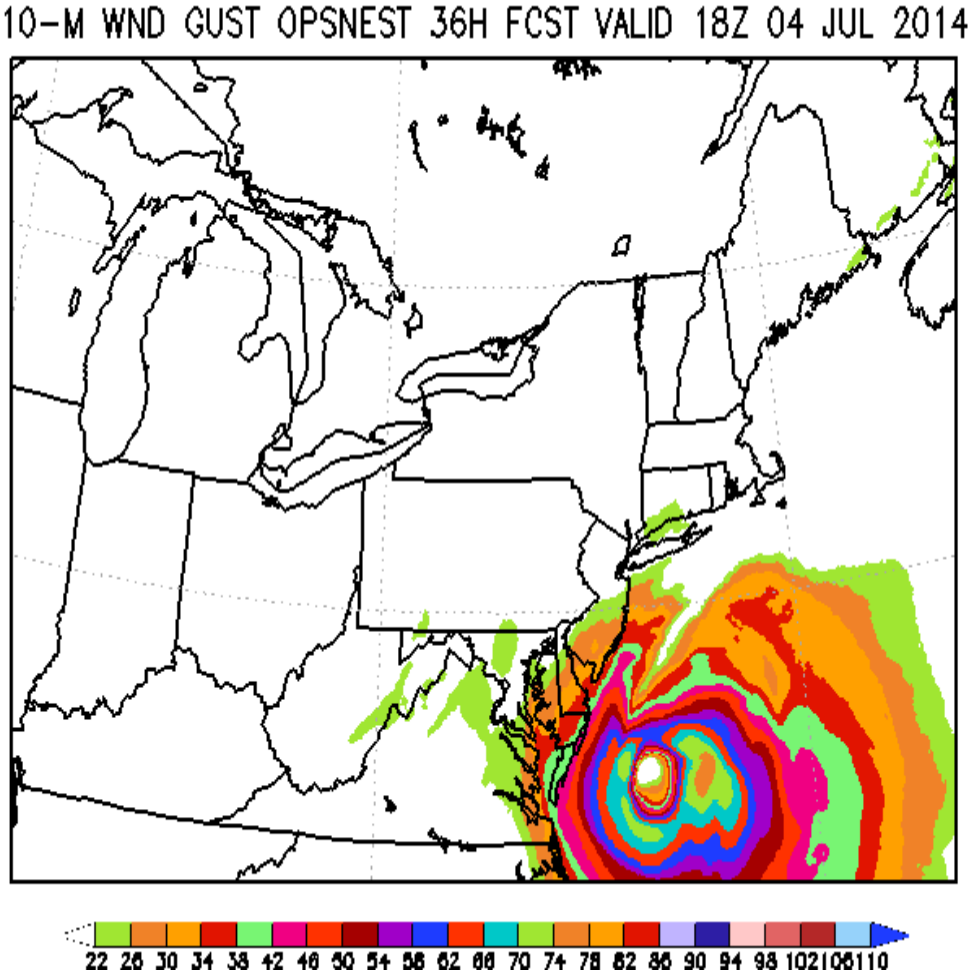
Ops vs Pll NAM runs of Arthur

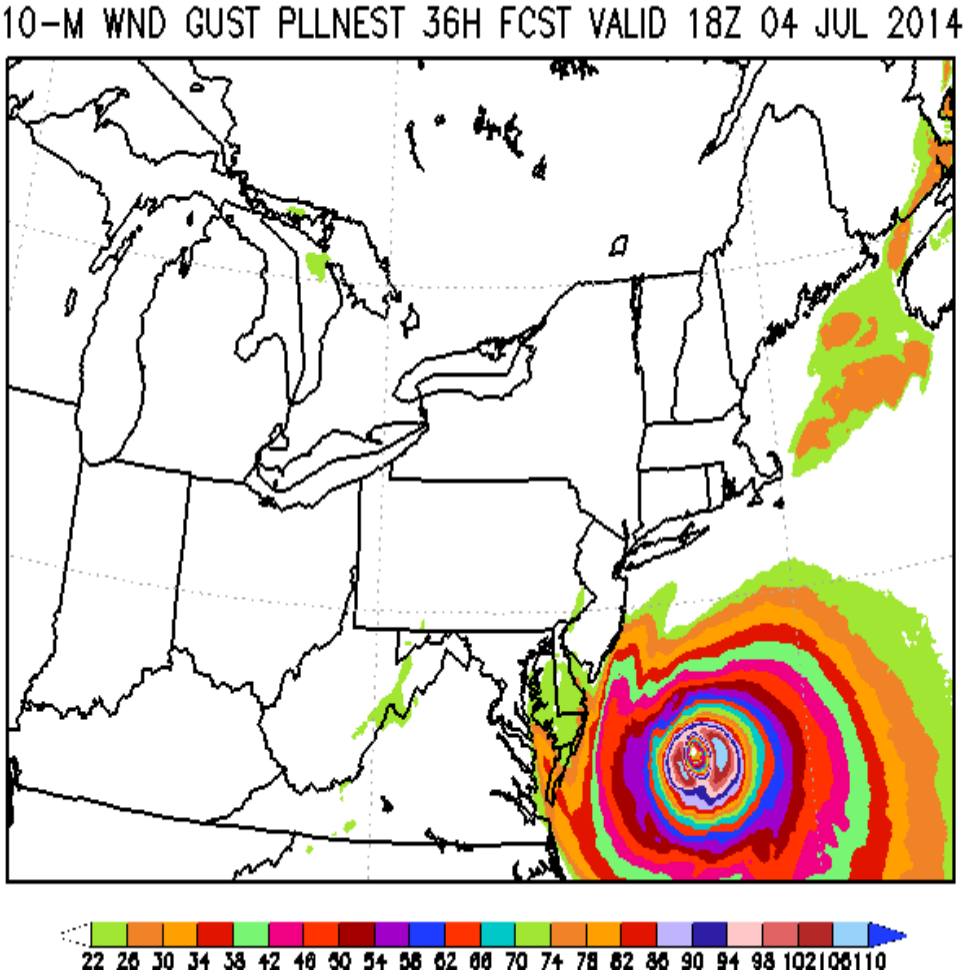
- **Parallel NAM runs on 1 July were too slow in tracking Arthur northeastward**
- **For later forecasts, the parallel NAM picked up on the move of Arthur into Nova Scotia about 24-h before the ops NAM did**
- **Parallel 4-km nest predicted a stronger storm closer to the observed wind speeds (with caveats)**
- **Arthur at 18z 4 July 14:**

SUMMARY OF 200 PM EDT...1800 UTC...INFORMATION

LOCATION...38.5N 72.4W
ABOUT 125 MI...200 KM ESE OF ATLANTIC CITY NEW JERSEY
ABOUT 255 MI...410 KM SSW OF CHATHAM MASSACHUSETTS
MAXIMUM SUSTAINED WINDS...90 MPH...150 KM/H
PRESENT MOVEMENT...NE OR 45 DEGREES AT 25 MPH...41 KM/H
MINIMUM CENTRAL PRESSURE...977 MB...28.85 INCHES

36-h wind speed gust forecast from 06z 7/3/14 NAM 4 km CONUS nest

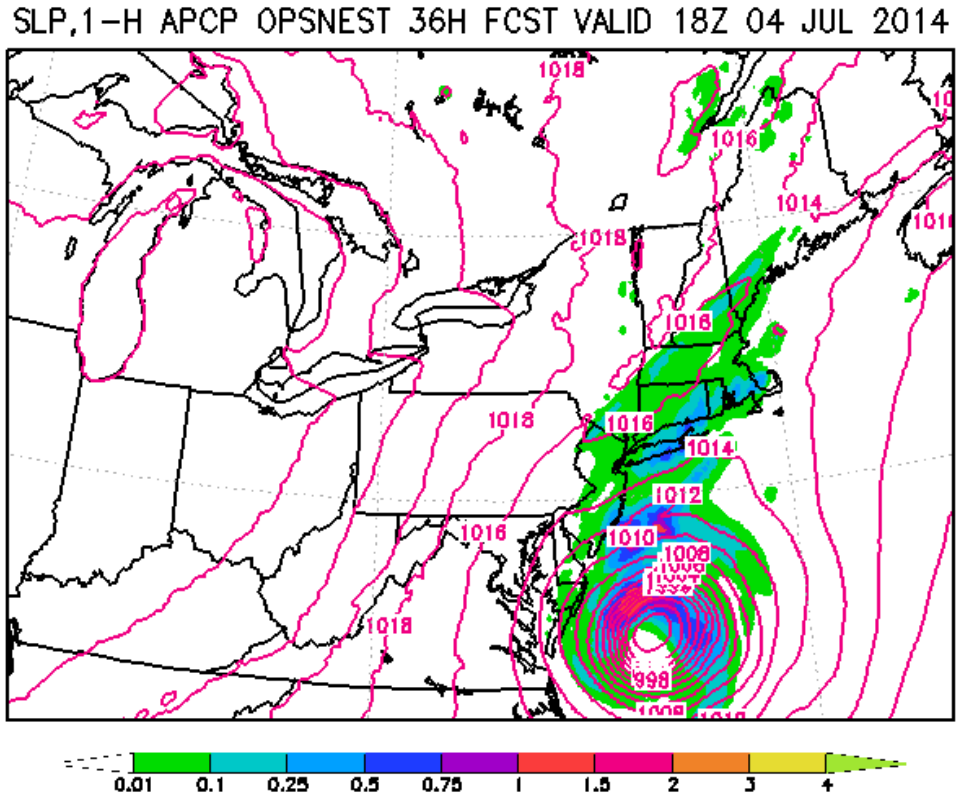




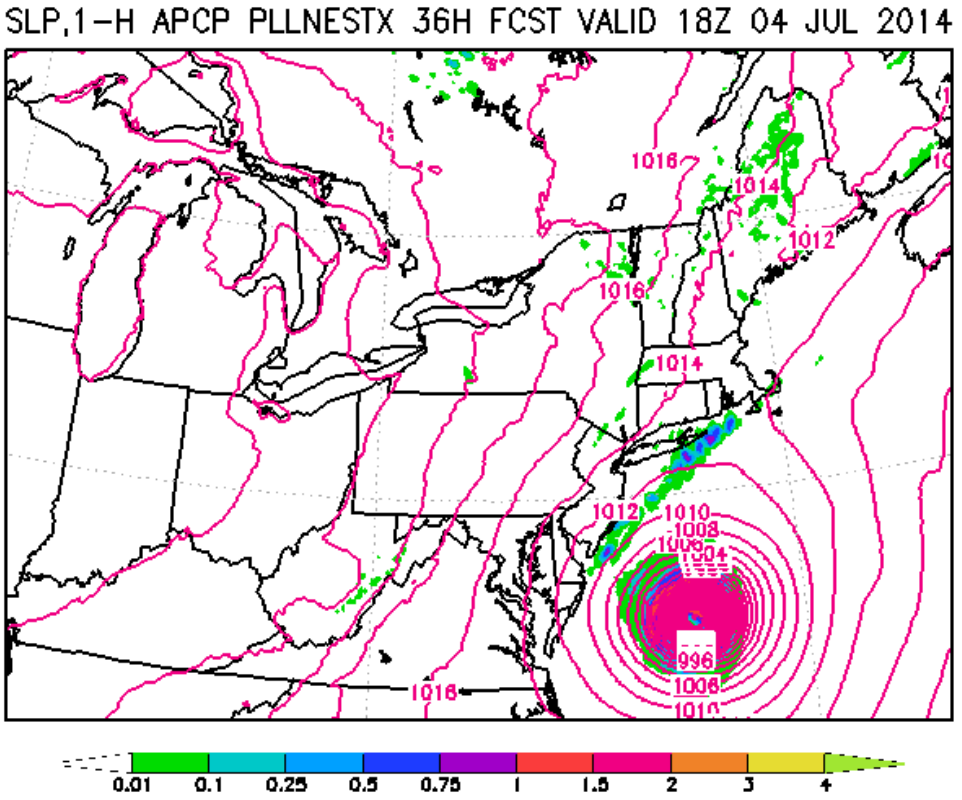
- Max wind 58-62 kt (not shown)
- Max wind gust 74-78 kt

- Max wind 82-86 kt (not shown)
- Max wind gust 106-110 kt

36-h SLP forecast from 06z 7/3/14 NAM-4

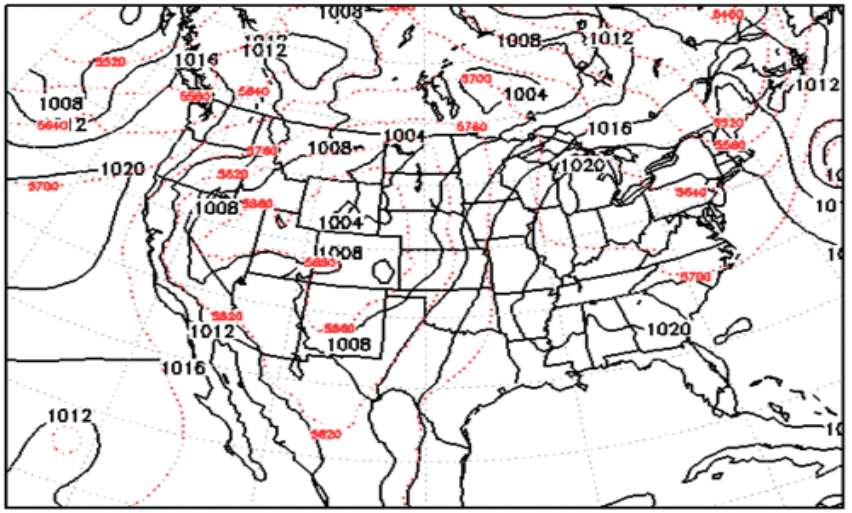


•Fcst position/central pressure
•37.7 N 73.9W (obs 38.5N 72.4W)
•989 mb (12 mb too weak)

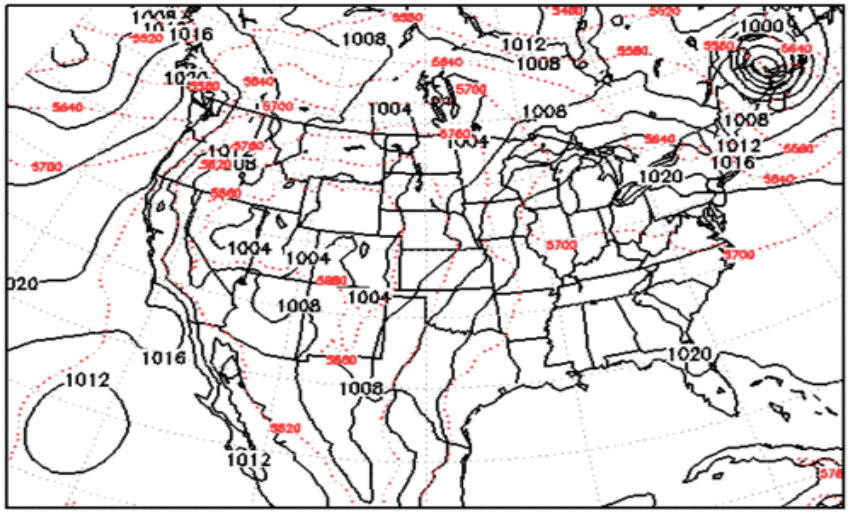


•Fcst position/central pressure
•37.7 N 72.5W (obs 38.5N 72.4W)
•954 mb (23 mb too strong)

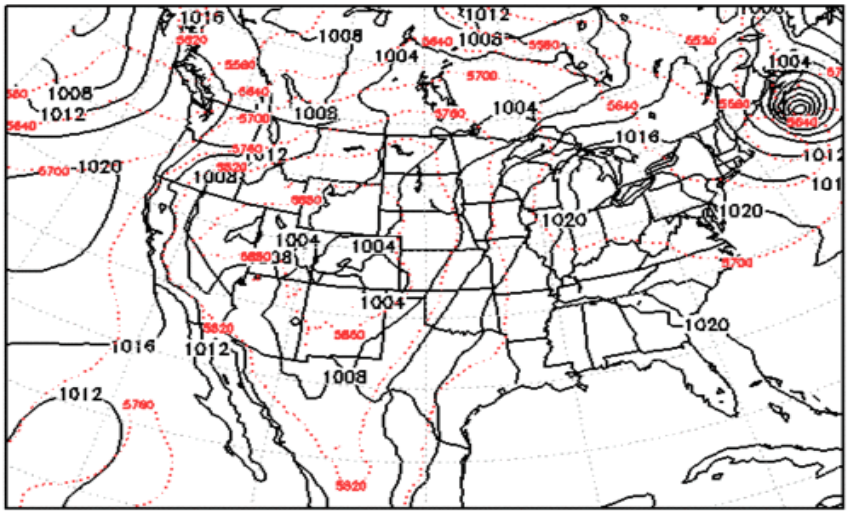
SLP NAM 72H FCST VALID 00Z 06 JUL 2014



SLP NDAS 00H ANL VALID 00Z 06 JUL 2014

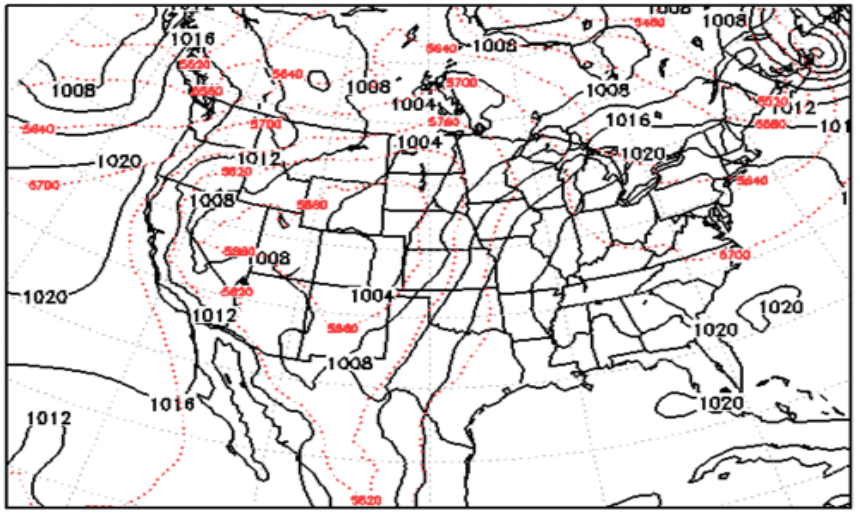


SLP NAMX 72H FCST VALID 00Z 06 JUL 2014

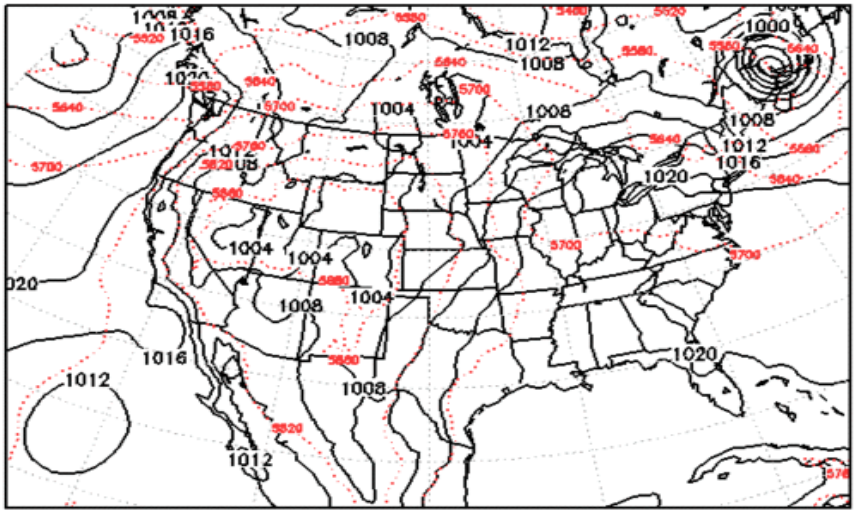


72-h fcst from 00z 7/3/14;
Note stronger storm in parallel

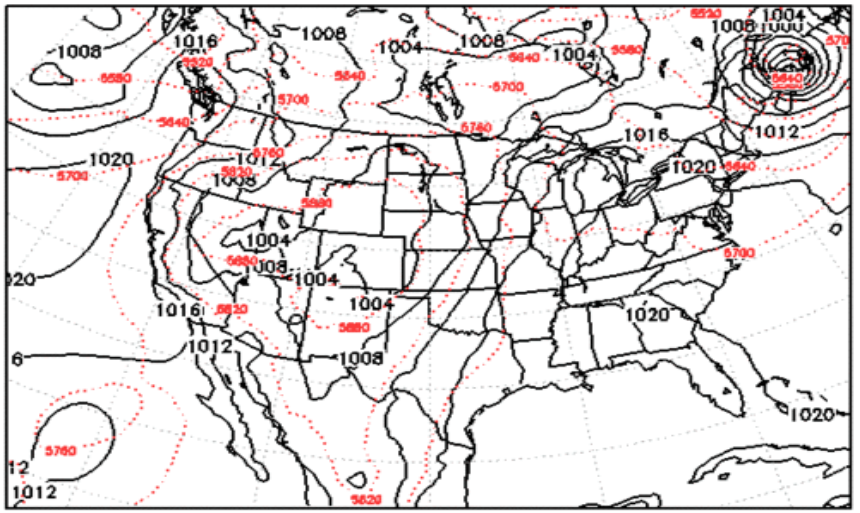
SLP NAM 60H FCST VALID 00Z 06 JUL 2014



SLP NDAS 00H ANL VALID 00Z 06 JUL 2014

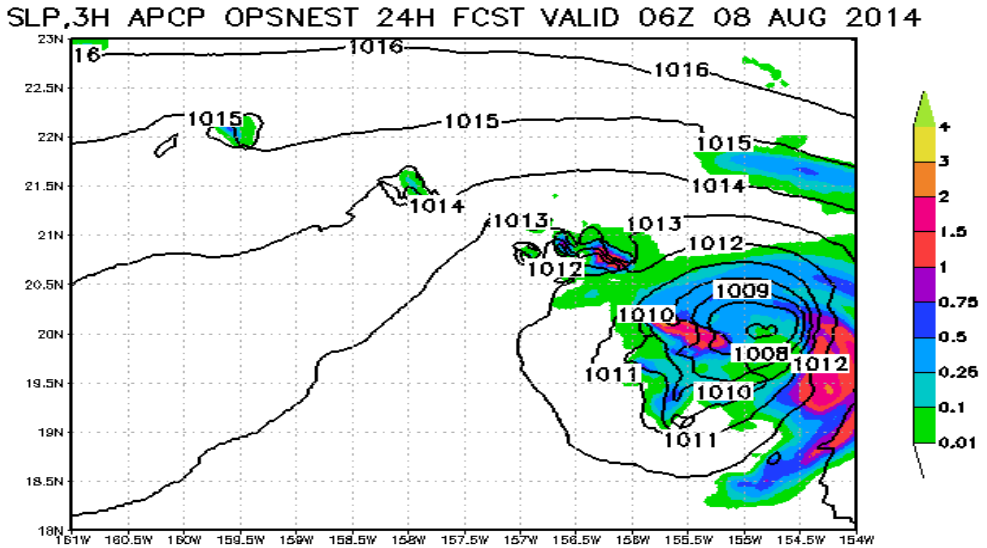


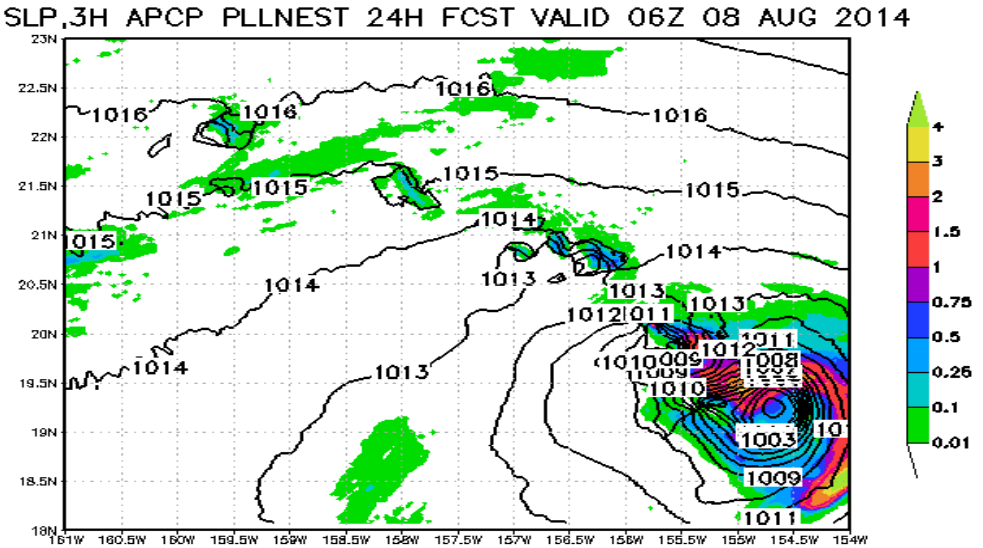
SLP NAMX 60H FCST VALID 00Z 06 JUL 2014

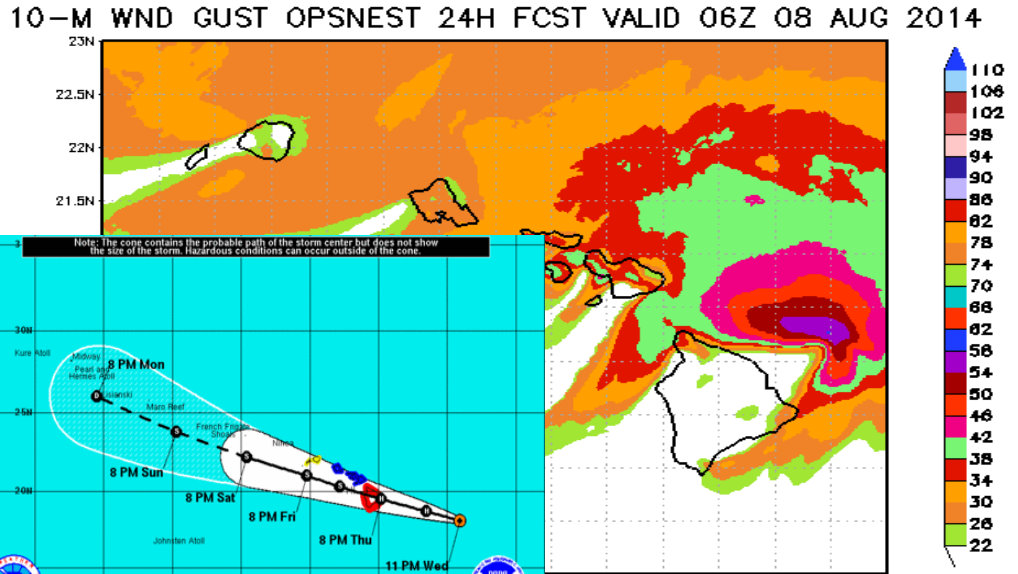


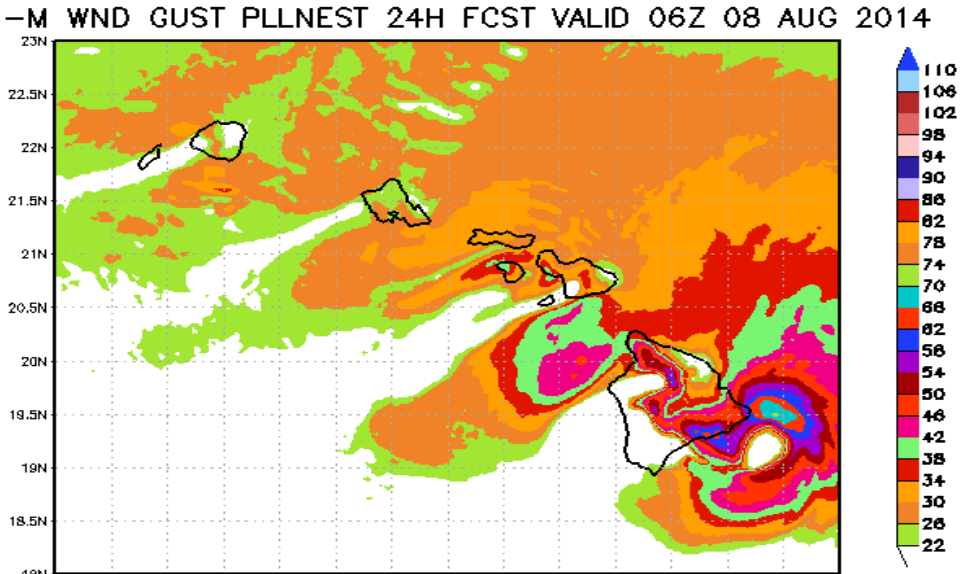
60-h fcst from 12z 7/3/14;

Hurricane Iselle example from Hawaii nest; 24-h fcst valid 06z 8/8 (8 pm HST Thu 8/7)

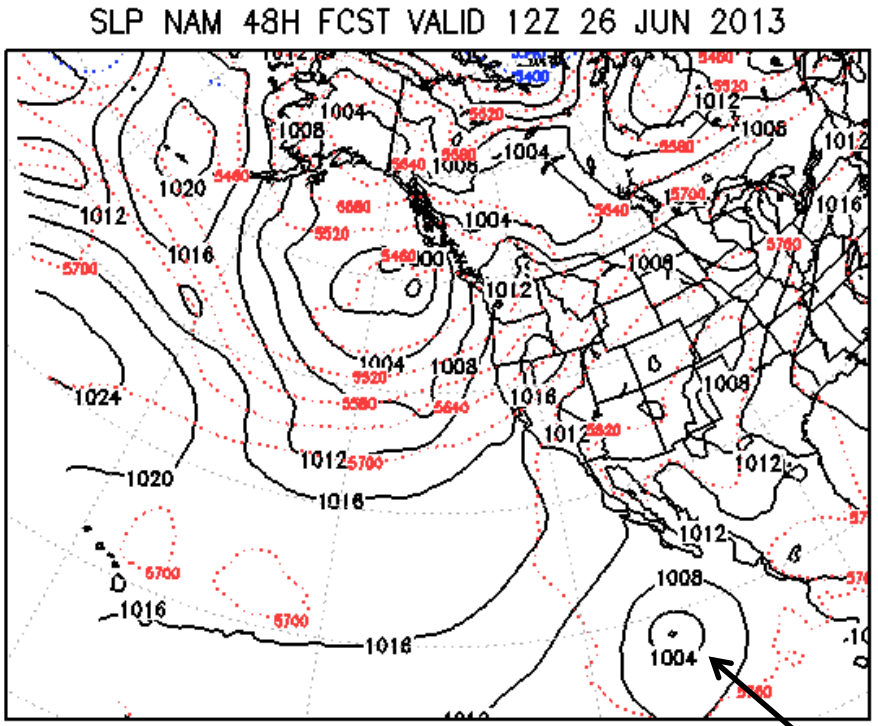


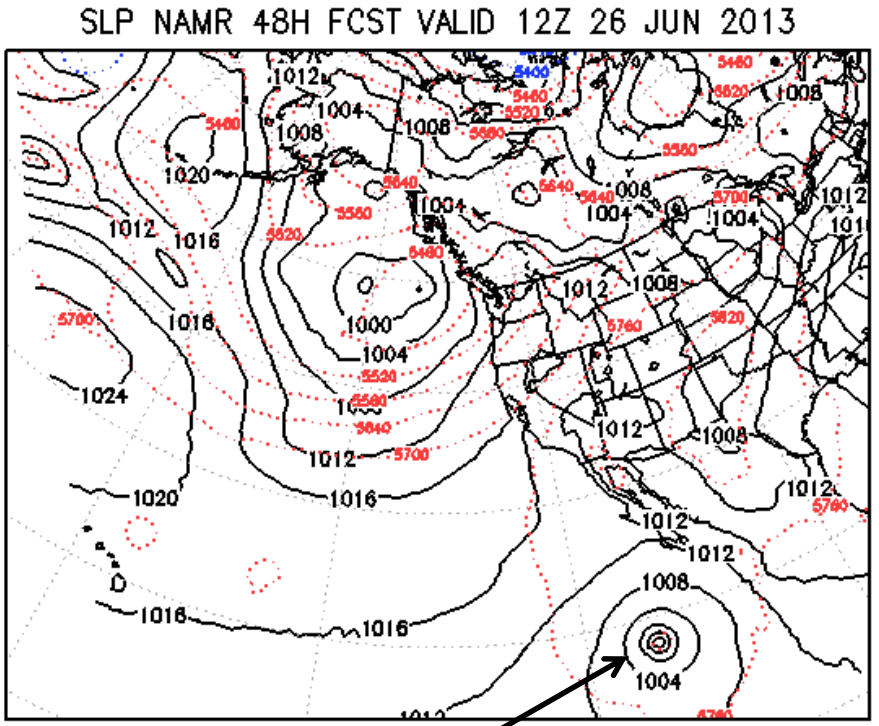






EPAC hurricane example from 2013 summer retrospective





Hurricane COSME; at 0900 UTC 6/26/13
Observed Central Pressure 983 mb
Observed Position 18.4N 114.5W

Known Issues

- Winter daytime cool bias
  - Causes:
    - Too much low cloud in southerly return flow
    - Soil too moist
  - Mitigation : NOAH LSM tuning, PBL/Microphysics tuning for low-level cloudiness
- Para NAM 4-km nest has higher QPF bias during warm season
  - Causes:
    - Pll nest running explicit convection
    - Decrease in critical threshold for condensation from 100% to 98% (done to improve 12km QPF bias)
  - Mitigation: Tuning/modifications in microphysics

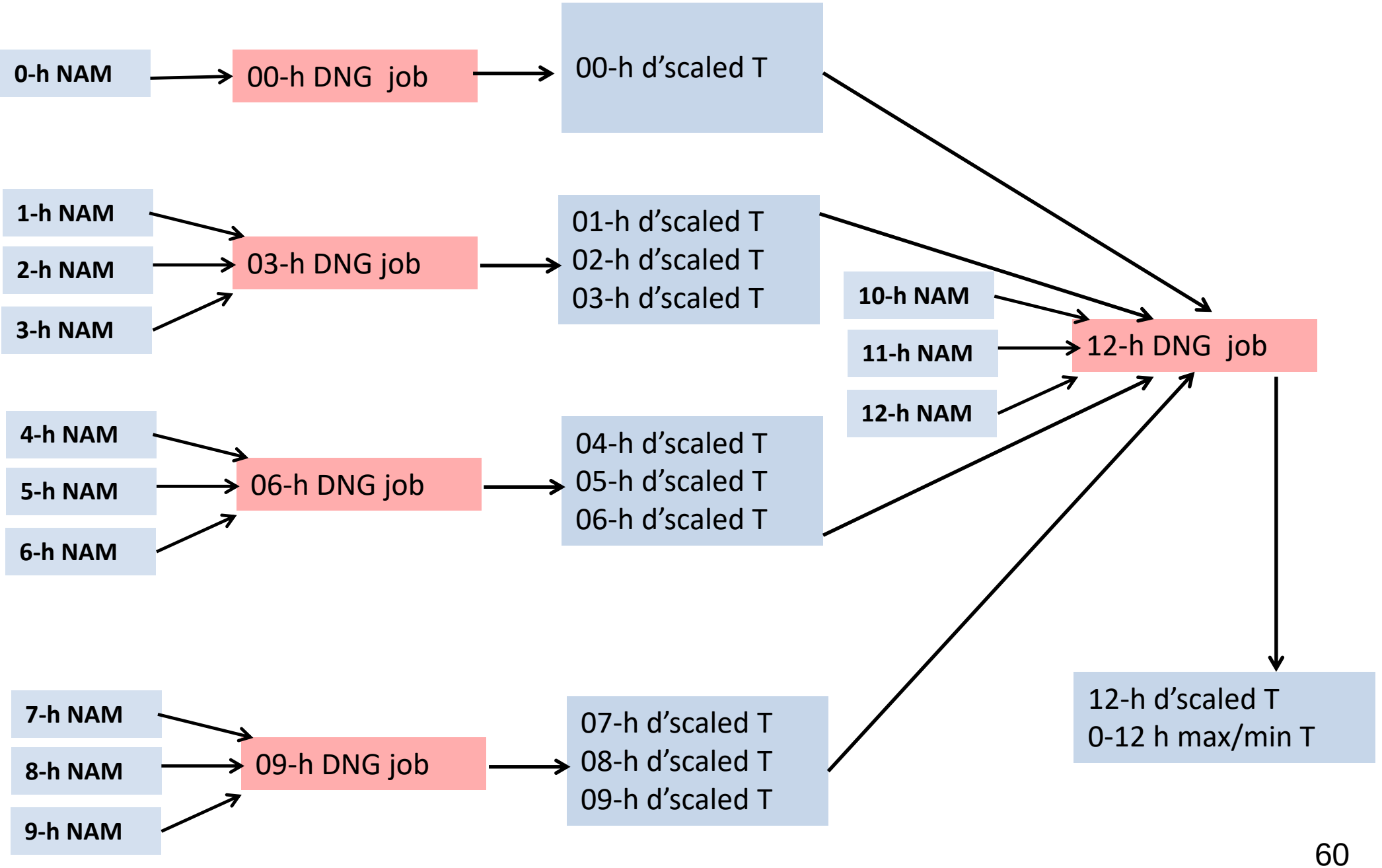
Known Issues

- **Cloud ceiling / cloud base height differences (too low in Pll NAM-12)**
  - **Possible contributing causes**
    - **Reduced RH threshold (from 100% to 98%) for cloud condensation**
    - **BMJ changes**
    - **Reduced horizontal diffusion of moisture (improved simulated radar, finer scale structures)**
    - **Soil too moist -> PBL too moist (?)**
    - **RRTM replaces GFDL radiation; RRTM more responsive to clouds → more complex cloud-radiation-PBL interactions**
  - **Mitigation**
    - **Z. Janjic has proposed PBL change to remove some of the low cloud; change will be mostly effective over ocean and some points over land where there is a thin layer of moist convective instability near the top of the PBL**
    - **Other areas over land: solution is less obvious; cloud-base height verification suggests low bias in AM in 12 km parallel, not so in 4-km CONUS nest. Preliminary tests by D. Lippi showed improved cloud heights (by removing excessive low cloud) for one case from April 2013 by diverting all BMJ convection into shallow component. Will continue to examine this in the context of our monthly telecons.**

Known issues : NAM DNG grids hourly temperature glitch

- NAM DNG grids output at 3-h intervals (00,03,06,09,12…) ; one of the elements is 12-h max/min Temp
- During original DNG development, problem was how to bring in hourly temperature info from NAM to compute max/min T at 12-h, 24-h, 36-h, etc.
- Solution : write hourly temp records in 3-hourly GRIB files (i.e., 03-h DNG file would have T at 1-h and 2-h, 06-h DNG file would have T at 4-h and 5-h, and so forth)
- With this setup, 12-h DNG job only has to read in 4 extra GRIB files, not each hourly NAM grid from 0-12 h, to compute 12-hourly max/min T
- Problem : fcst hour GRIB labels for hourly T records are flipped. In 03-h file, hour 1 is labeled as hour 2, hour 2 is labeled as hour 1. In 06-h file, hour 4 is labeled as hour 5, hour 5 is labeled as hour 4, etc. ***Bug is in both ops and pll NAM smartinit codes***
- Flipped forecast hour labels have no adverse impact since they are used only for 12-h max/min T computation only, so it was never detected. This was apparently never noticed before by the field because only the 3-hourly T from NAM DNG is processed for AWIPS
- Matt Foster of NWS Central Region discovered this bug while ingesting the parallel NAM DNG grids into AWIPS2
- It was decided to fix this after the NAM implementation, as either a crisis fix to the NAM DNG code or in the next NAM DNG/RTMA implementation later this year.

NAM DNG files; 2-m T logistics



Summary/Conclusions

1. Improving large-scale synoptic performance, especially at day 2-3 (more so during cool season)
2. Higher warm-season QPF bias in 12 km parent
3. Dramatically improves convective structures in the CONUS 4 km nest
4. Dropping legacy GFDL radiation for RRTM allows for better collaboration on radiation scheme enhancements with global branch
5. Regular meetings/telecons with NCEP Service Centers (SPC, WPC, AWC) were a great help during development testing; will continue with these, plus plan to bring the NWS Regions into this loop.